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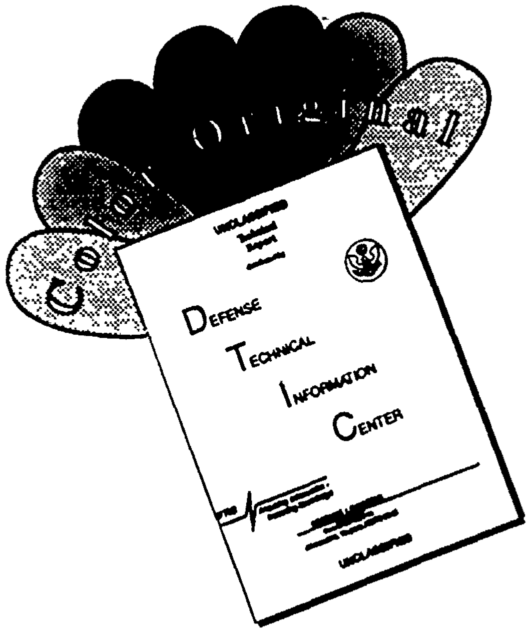

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In summer 1975, heavy rains in the southern part of the Red River basin prompted some Minnesota farmers to construct their own levees. These levees prevented flooding of thousands of acres of cropland. This success led to extensive agricultural levee construction by farmers on both sides of the river. Various Federal and State agencies expressed concern over the potential adverse impacts of uncontrolled levee construction. The Corps of Engineer's analysis showed that continued levee construction would significantly increase flood stages and velocities, with adverse impacts possibly extending as far downstream as Canada. On the basis of this analysis, both North Dakota and Minnesota declared a moratorium on additional levee construction and began developing joint criteria to regulate agricultural levee construction.

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RED RIVER OF THE NORTH MAIN STEM

TECHNICAL INFORMATION REPORT

(WITH SPECIAL EMPHASIS ON AGRICULTURAL LEVEES)

CORPS OF ENGINEERS
ST. PAUL DISTRICT

JULY 1982

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INTRODUCTION

In summer 1975, heavy rains in the southern part of the Red River basin prompted some Minnesota farmers north of Grand Forks, North Dakota, to construct their own levees. These levees prevented flooding of thousands of acres of cropland. This success led to extensive agricultural levee construction by farmers on both sides of the river. As of the latest surveys, approximately 36 miles of agricultural levees are on the Minnesota side and 19 miles of levees are on the North Dakota side.

Various Federal and State agencies expressed concern over the potential adverse impacts of uncontrolled levee construction. In 1977, at the request of the States of Minnesota and North Dakota, the St. Paul District examined these agricultural levees. Our analysis showed that continued levee construction would significantly increase flood stages and velocities, with adverse impacts possibly extending as far downstream as Canada. On the basis of this analysis, the two States declared a moratorium on additional levee construction and began developing joint criteria to regulate agricultural levee construction.

The agricultural levees have been in place during three major floods - in 1975, 1978, and 1979. The behavior of the levees during these floods substantiated the conclusions of the District's hydraulic analysis. The stages for the 1978 and 1979 floods were nearly 1 foot higher than they would have been without the levees. In addition, the levees were overtopped or failed in numerous places in 1978 and 1979.

In early 1980, the Governors of Minnesota and North Dakota, with limited involvement by the Manitoba Government, agreed on levee criteria. The primary requirement is that the levees may not increase the stage of the 100-year flood on the Red River by more than one-half foot. The criteria also specify other standards for construction and interior drainage. Section J of the agreement allows for exceptions to the one-half foot criteria. Under the authority of this section, the Governors directed the local water management organizations to develop a compromise plan for the existing agricultural levees.

The Corps has functioned as a technical consultant to the States and local agencies, providing engineering information on the main stem and the agricultural levees. Much of the information contained in this report has already been presented to and coordinated with the State and local agencies over the past several years. This report consolidates the results of the Corps' analysis of the Red River main stem from Grand Forks to the international border. The overall report consists of three major sections:

I. Analysis of Existing Agricultural Levees and Proposed Modifications

II. Feasibility Analysis of Main Stem Alternatives

III. Guidelines for Agricultural Levee Construction

TECHNICAL NOTES

FLOOD FREQUENCIES

In 1971, the U.S. Geological Survey completed a report defining the regional flood for the Red River. This report was prepared in cooperation with the States of Minnesota and North Dakota, Corps of Engineers, and Soil Conservation Service. In 1972, the regional flood profile and discharges were adopted for use by the various State and Federal agencies. The regional flood is that flood which has a 1-percent chance of being equaled or exceeded in any given year; over a long period of time, it will have an average recurrence interval of 100 years. This flood, commonly referred to as the 1-percent chance or 100-year flood, is used by both States for floodplain management on the main stem. The States' criteria on agricultural levees also relate maximum allowable stage increases to this particular flood profile.

Corps of Engineers regulations specify that the most up-to-date frequency curves must be used for the planning and design of Corps projects. Several major floods have occurred since 1972. Discharge data for these floods and for three floods in the last half of the 19th century have led to revisions in the Corps' frequency curves. The changes are not considered significant enough to warrant revising the 1972 interagency flood frequency data, but may cause some confusion because two sets of frequency curves are being used for the Red River. For instance, the 1972 interagency discharge of the 1-percent chance (100-year) flood at Grand Forks is 89,000 cfs (cubic feet per second), but the Corps uses a 1-percent chance discharge of 106,000 cfs for its planning and design work. In keeping with the purpose of this report and at the request of the States, only the 1972 interagency flood frequencies are used for this analysis. A table of flood flows and frequency curves are included in Appendix B.

COMPUTER MODELS

The principal model used in our analysis of the agricultural levees is the HEC-2 water surface profile model. This model determines the changes in

water surface elevations resulting from encroachments in the floodplain such as levees, bridges, etc. Additional models include the HEC-5 basin high-flow model and the EAD (Expected Annual Flood Damage) economic model, both developed by the Hydrologic Engineering Center, and the Vicksburg Crop Damage Program developed by the Waterways Experiment Station.

DATA BASE

Accurate information on the main stem is essential for accurate computer modeling. The Corps' agricultural levee analysis is based on the following data:

- 78 valley sections along the main stem from Grand Forks to the Canadian border at intervals of approximately 1 mile (surveyed 1978).

- Profiles of existing agricultural levees (surveyed 1978, resurveyed 1979).

- U.S. Geological Survey gaging records on stages and discharges of recent floods on the Red River.

- High-water marks along the Red River and tributaries for recent floods. All were set and surveyed by the Corps except for the high-water marks for the 1975 summer flood. These were obtained by the Middle River-Snake River Watershed District.

- Sketches of bridges and bridge approaches furnished by State transportation departments (the following bridges and approaches were resurveyed in 1978 and 1979: Highway 1/54, Oslo railroad, Highway 317/17, Highway 11/66, Highway 175/5, Highway 171).

- U.S. Geological Survey topographic maps and aerial photos used to supplement floodplain data.

- 1972 interagency discharges for the 1-percent chance flood on the Red River (91,000 cfs at Oslo and including river milages of identifiable landmarks).

- Economic surveys of urban and rural damages (completed June 1981).

REACHES

For this analysis, the study area was broken down into six reaches along the Red River main stem, as shown in the following table. These reaches as well as the bordering townships are illustrated on figures 1a, 1b, and 1c.

Table 1 - Identification of study reaches

Reach	River miles	Extension
1	295.7 - 287.0	Grand Forks to upstream end of the existing agricultural levee system.
2	287.0 - 271.2	Upstream end of the existing agricultural levee system to Oslo, Minnesota.
3	271.2 - 255.0	Oslo to downstream end of North Dakota levees.
4	255.0 - 236.0	Downstream end of North Dakota levees to downstream end of Minnesota levees.
5	236.0 - 206.7	Downstream end of Minnesota levee system to Drayton, North Dakota.
6	206.7 - 155.0	Drayton to the international border.

OTHER AGRICULTURAL LEVEES

In this report, only the levees between river miles 287.4 and 236.0 were analyzed. Another levee section approximately 3.5 miles in length extends from river miles 188 to 184.5. This section is relatively small and does not significantly affect stage, flow, or velocity. Therefore, it has not been analyzed.

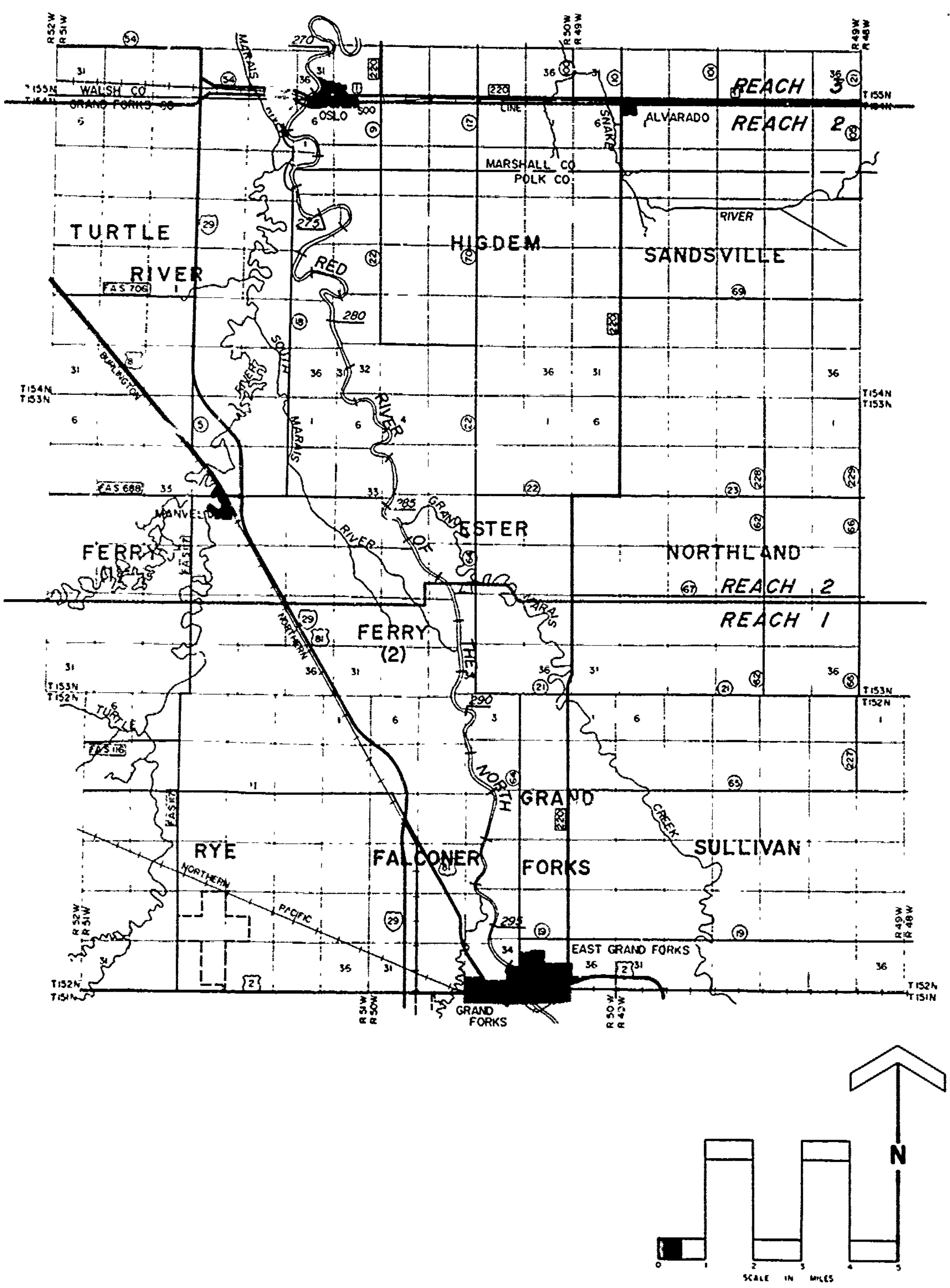


Figure 1a

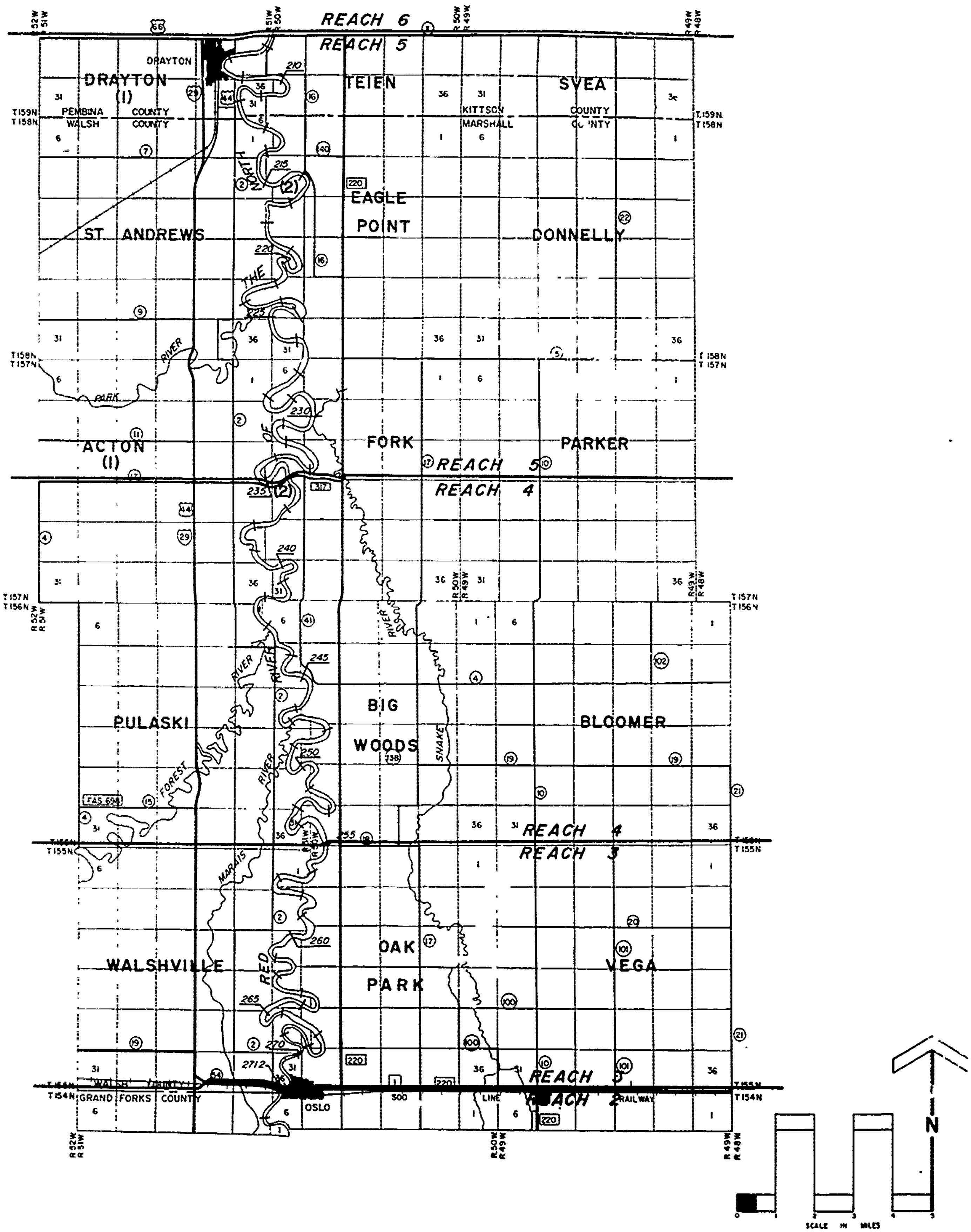
RED RIVER MAIN STEM

REACH I - REACH 2

RIVER MILE 271 - RIVER MILE 296

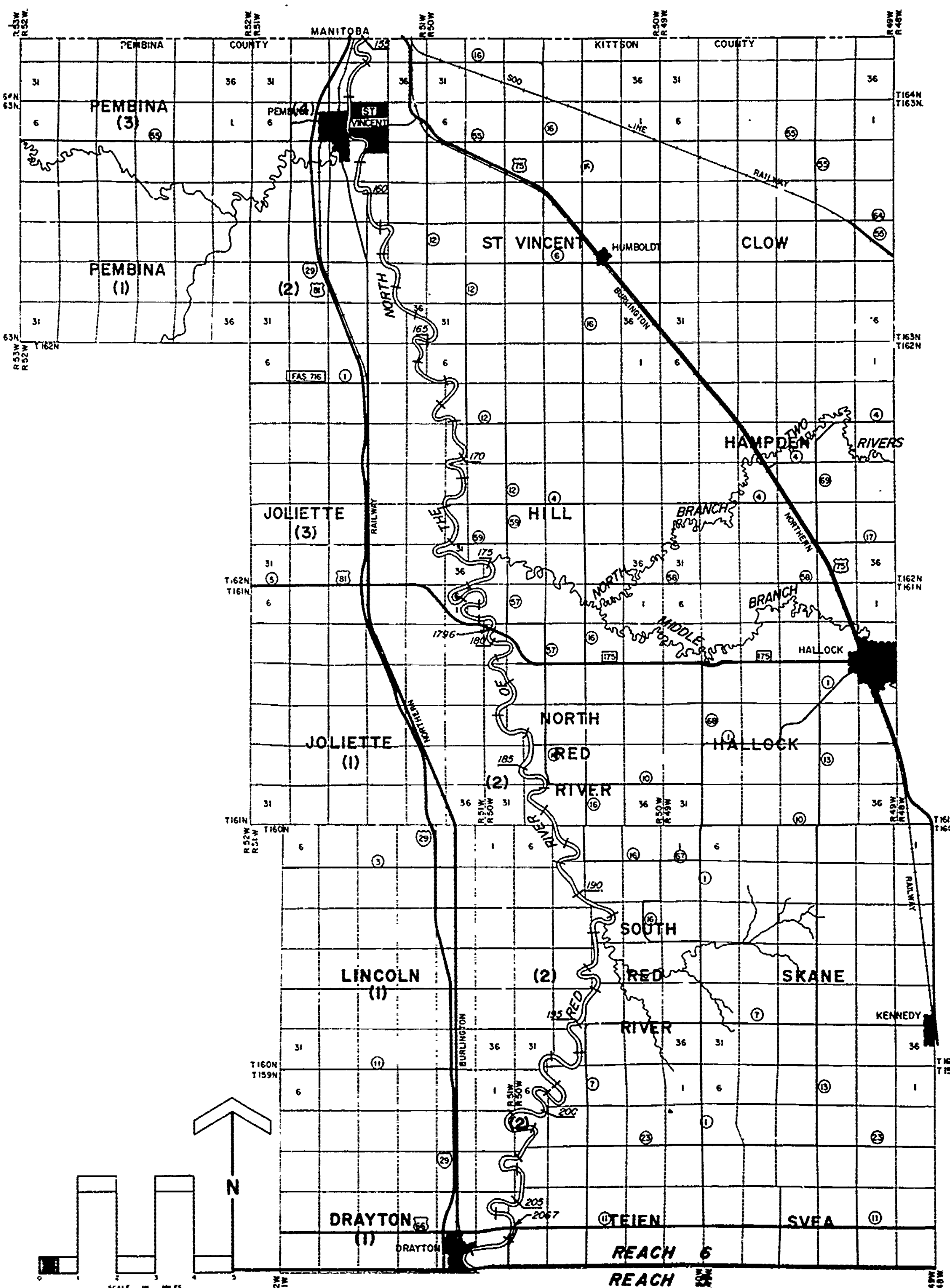
OSLO - GRAND FORKS

1981



RED RIVER MAIN STEM
REACH 3 - REACH 5
RIVER MILE 206 - RIVER MILE 271
DRAYTON - OSLO
1981

Figure 1b



RED RIVER MAIN STEM
REACH 6
RIVER MILE 155 – RIVER MILE 206
INTERNATIONAL BORDER–DRAYTON
1981

Figure 1c

I. ANALYSIS OF EXISTING AGRICULTURAL LEVEES AND PROPOSED MODIFICATIONS

A. BACKGROUND

Since its initial construction in summer 1975, the agricultural levee system has been continually modified and expanded. Figures 2, 3, and 4 show the alignments of the agricultural levees during the summer 1975, spring 1978, and spring 1979 floods, respectively. Table 2 summarizes the lengths of agricultural levees in place for each flood and each State.

Table 2 - Agricultural levees in place for the 1975, 1978, and 1979 floods

State	Length of levee (miles)		
	1975 flood	1978 flood	1979 flood
Minnesota	16	36	36
North Dakota	0	19	19

As the maps show, the levee system is not continuous and, in places, the levees tie into high ground or existing township roads. The data on levee lengths do not include those sections of township road that connect with the levees and function as part of the levee system. For the 1979 flood, approximately 3 miles of such roads were on the Minnesota side and 10 miles were on the North Dakota side.

As the levees were lengthened, their heights were being increased in numerous locations. Accurate data on levee elevations in 1975 and 1978 are lacking. Figure 5 represents the top elevations of Minnesota and North Dakota agricultural levees in summer 1979. This profile, as well as the alignment shown in figure 4, should be a reasonably accurate depiction of current conditions. Some levee raises have been verbally reported on the Minnesota side, as well as some levee lowering and removal on the North Dakota side. However, these changes have not been surveyed, and location and amount of modifications since 1979 remain unspecified.

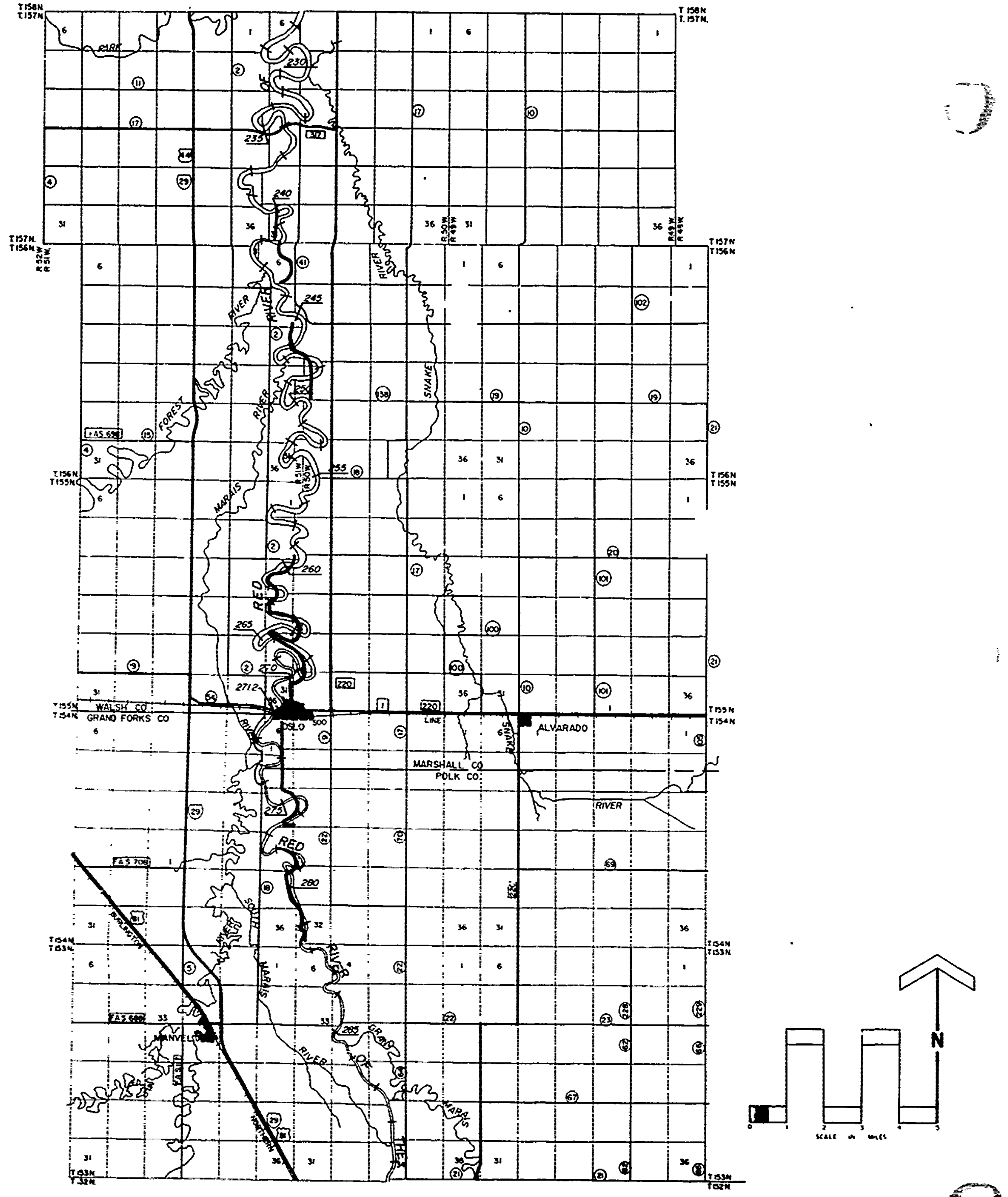


Figure 2

EXISTING 1975 (SUMMER) LEVEES

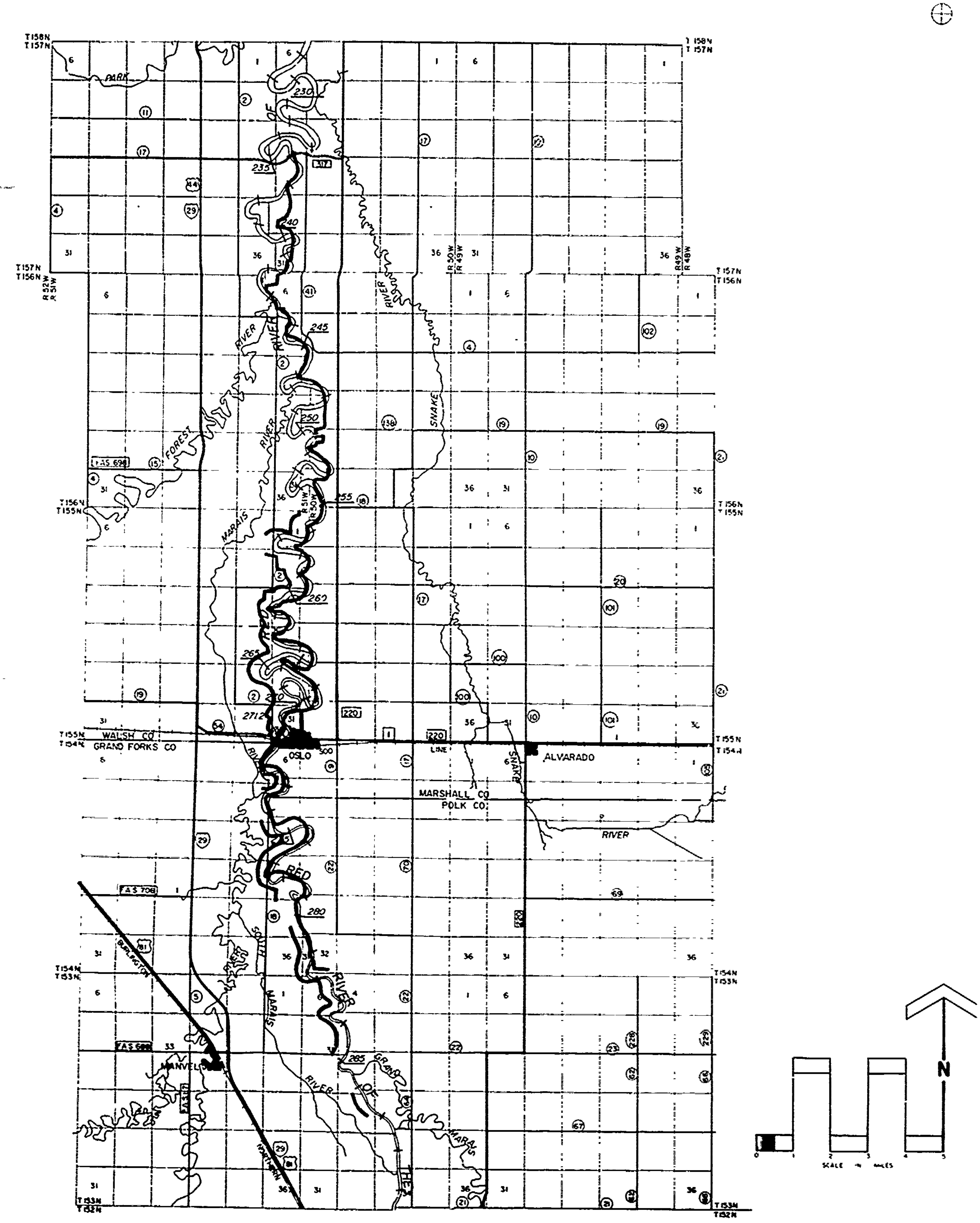


Figure 3

EXISTING 1978 LEVEES

RED RIVER MAIN STEM

REACH 2 - REACH 4

RIVER MILE 287 - RIVER MILE 236

1981

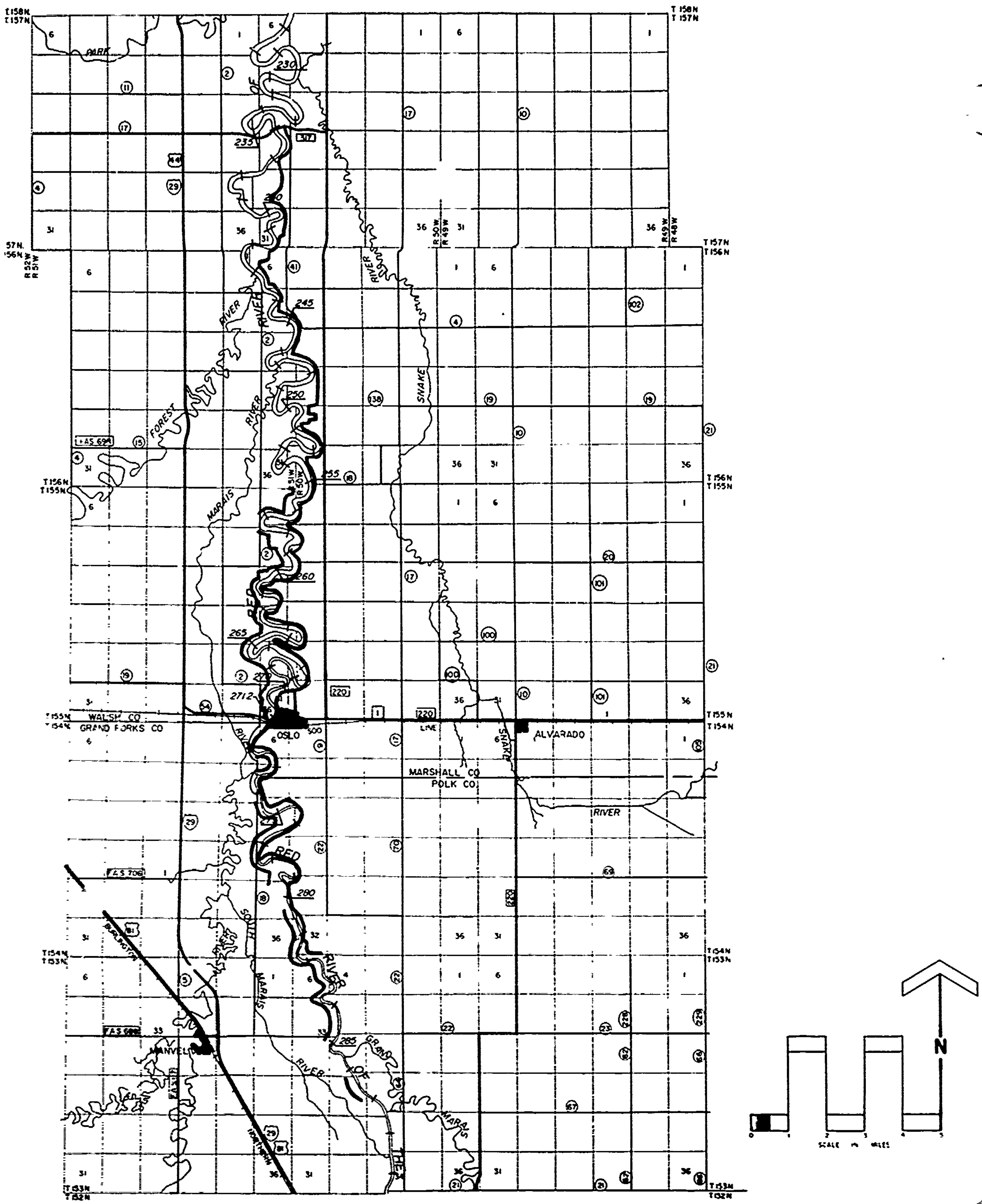


Figure 4

EXISTING 1979 (AND MAY 1981) LEVEES

RED RIVER MAIN STEM

REACH 2 - REACH 4

RIVER MILE 287 - RIVER MILE 236

1981

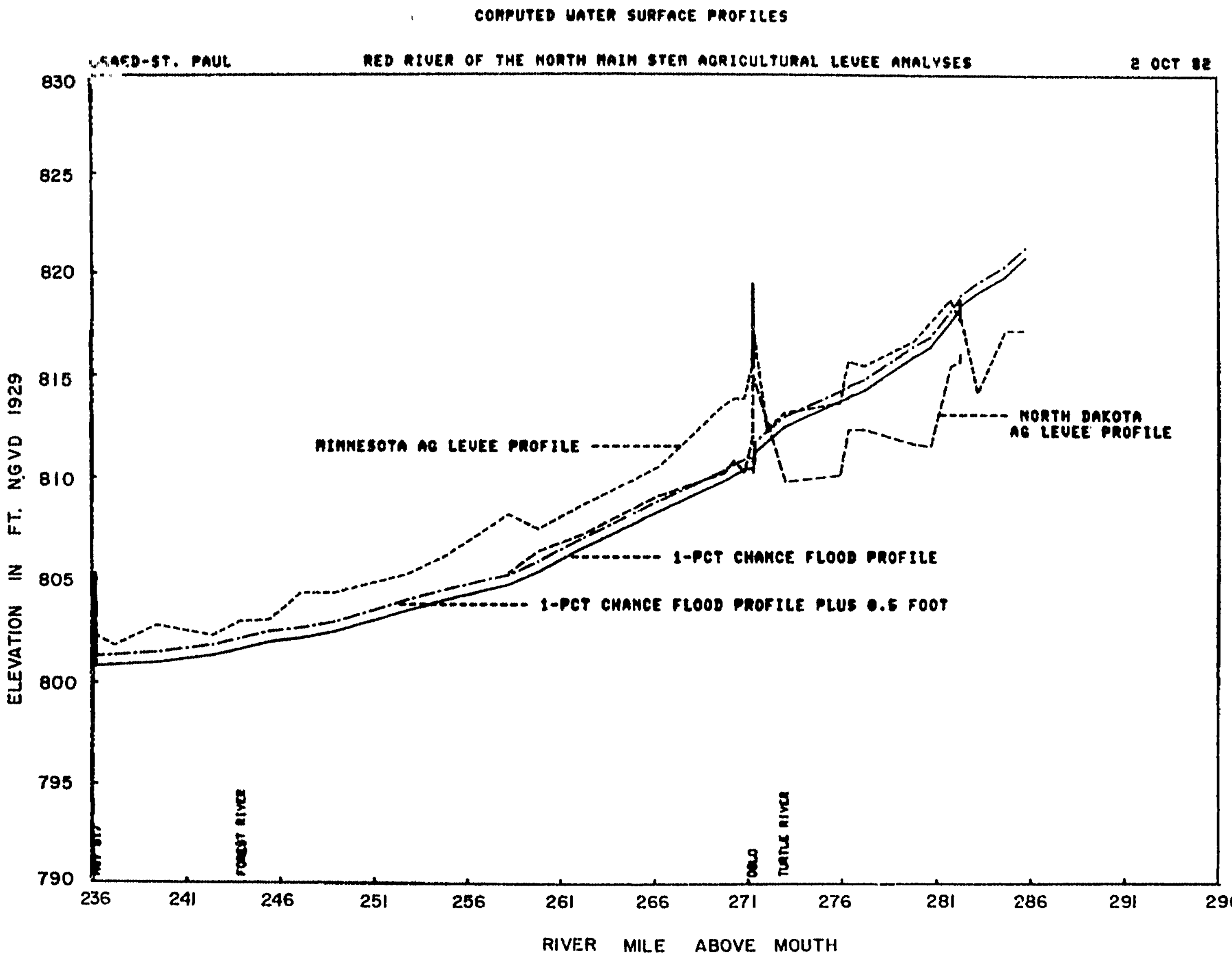


Figure 5 - Top elevations of levees in summer 1979

B. HYDRAULIC EFFECTS OF EXISTING LEVEES

The observed high-water profiles for the 1975, 1978, and 1979 floods as well as the profile for the 1-percent chance flood ("without levee" condition) are shown in figure 6. Using the HEC-2 model, we have also generated profiles representing the "without levee" condition for the 1975, 1978, and 1979 floods. These profiles are plotted in figures 7 (1975 flood), 8 (1978 flood), and 9 (1979 flood).

The profiles for the 1979 flood are of particular importance because the measured peak flow at Oslo, Minnesota, coincides with the discharge of the 1-percent chance flood (91,000 cfs). The observed stage at Oslo was 0.6 foot higher than it would have been for the same flow without agricultural levees. At locations downstream of Oslo, the stage increase is nearly 2 feet. In other words, for a flood equal to the 1-percent chance flood, the agricultural levees increased stages significantly over the one-half-foot increase allowed by the States' criteria. Therefore, the levee system as a whole does not meet the States' criteria. Figure 10 shows the rating curve at Oslo for "with levee" and "without levee" conditions.

The HEC-2 model indicates that the agricultural levees increase flow velocities. For the 1-percent chance flood, flow velocities in the overbank areas for both conditions (with and without levees) were computed to average approximately one-half fps (foot per second). In the main channel, flow velocities would increase significantly in areas where the levees constrict flow near the channel. This condition exists at the Minnesota Highway 317 bridge and at Oslo. Channel velocities at these locations change from 3 to 5 fps without levees to 5 to 8 fps with levees. Erosion potential increases in these areas and the structural integrity of the bridges and levees may be degraded. The North Dakota State Water Commission has reported increased erosion of the North Dakota floodplain downstream of Oslo. Sediment transport rate may also increase for the "with levee" condition.

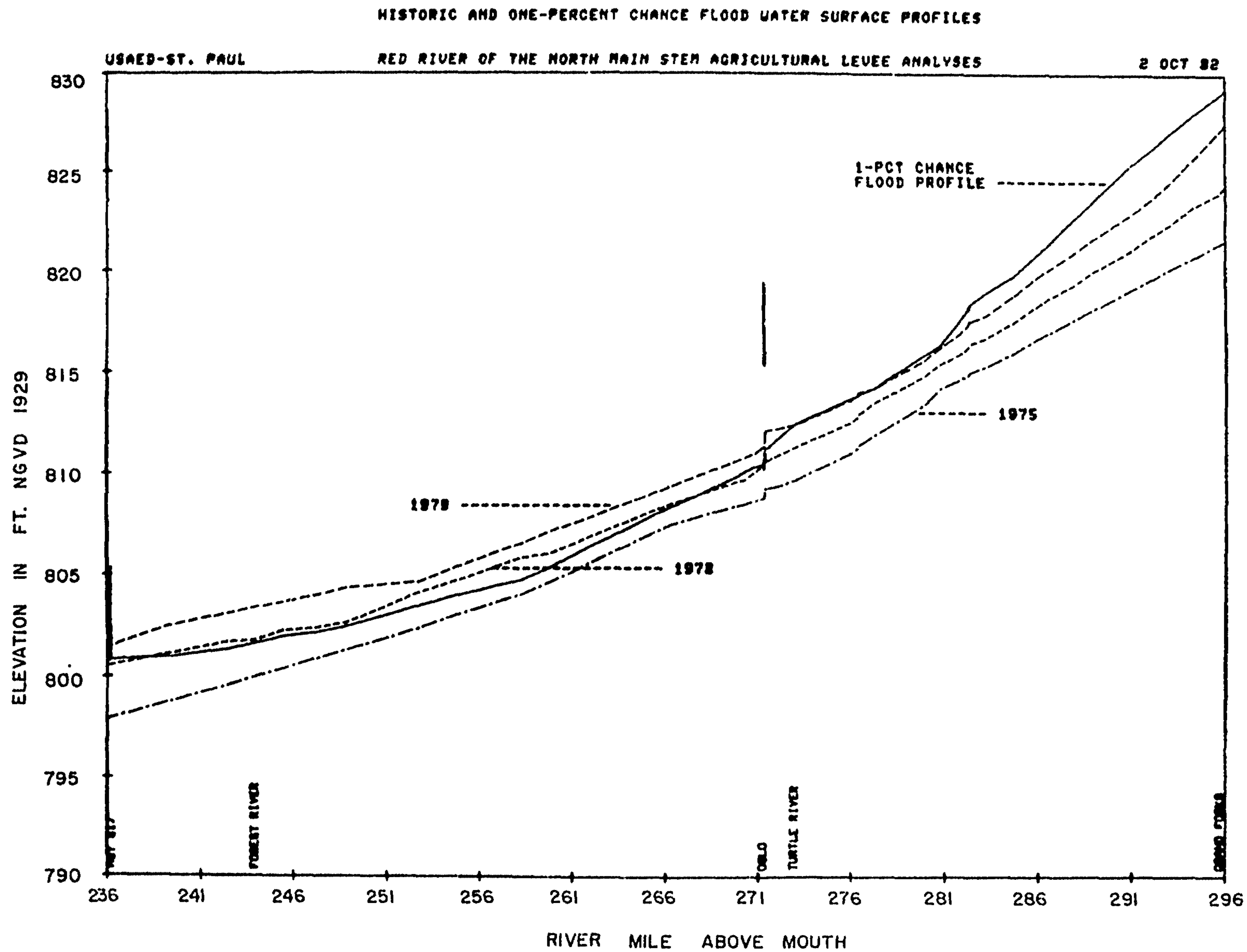


Figure 6 - Historic water surface profiles and computed 1-percent chance flood profile (1972 condition)

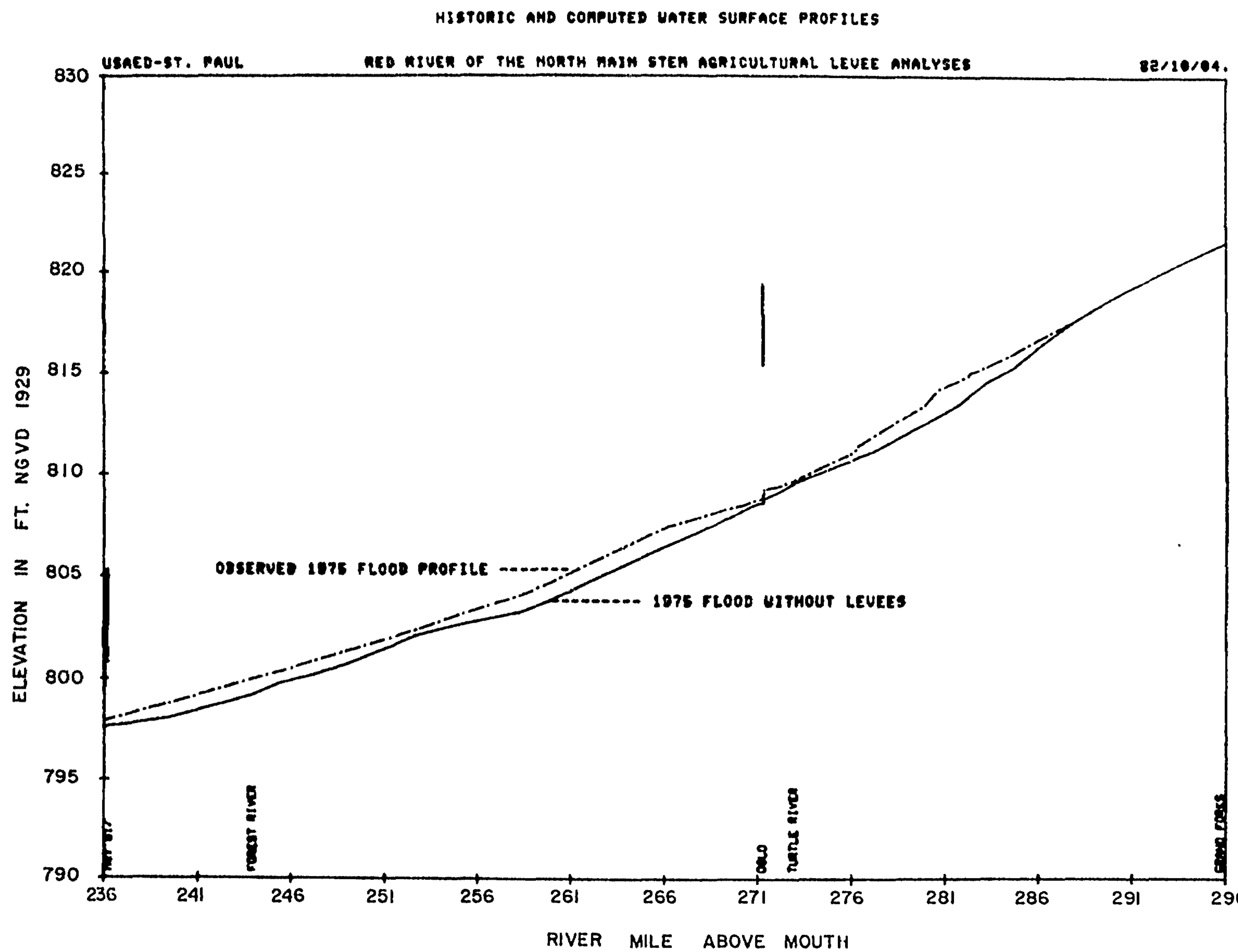


Figure 7 - Water surface profiles, 1975

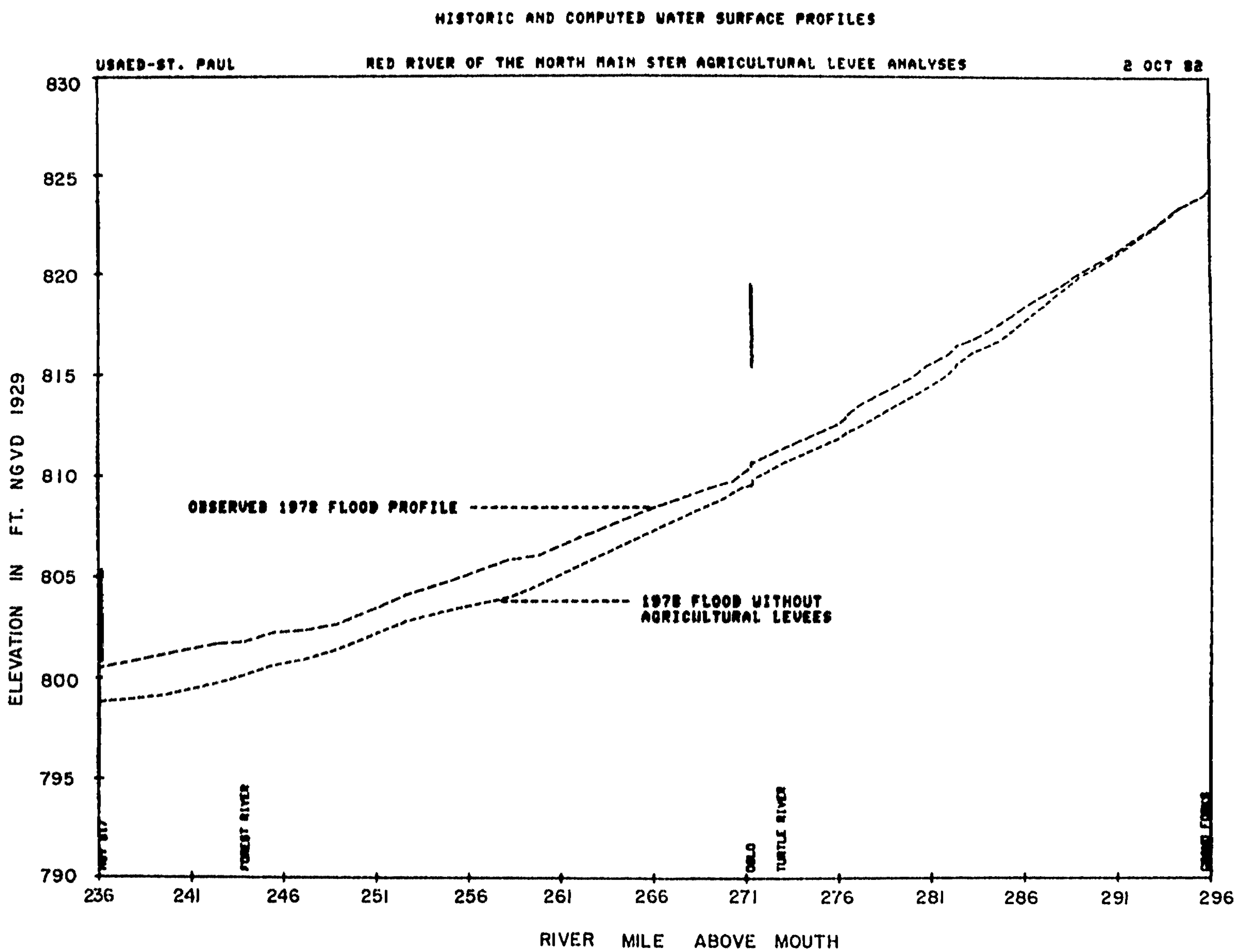


Figure 8 - Water surface profiles, 1978

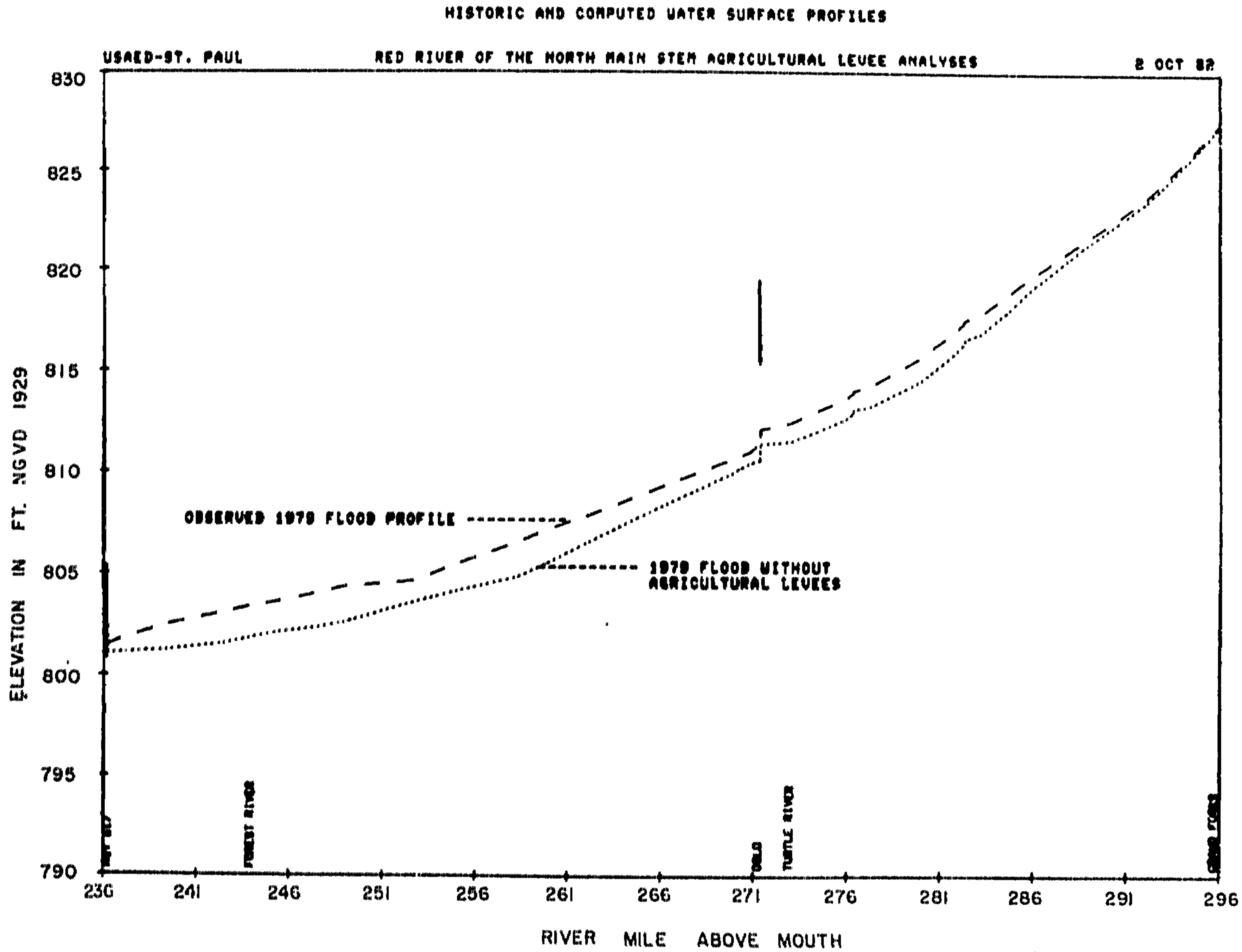


Figure 9 - Water surface profiles, 1979

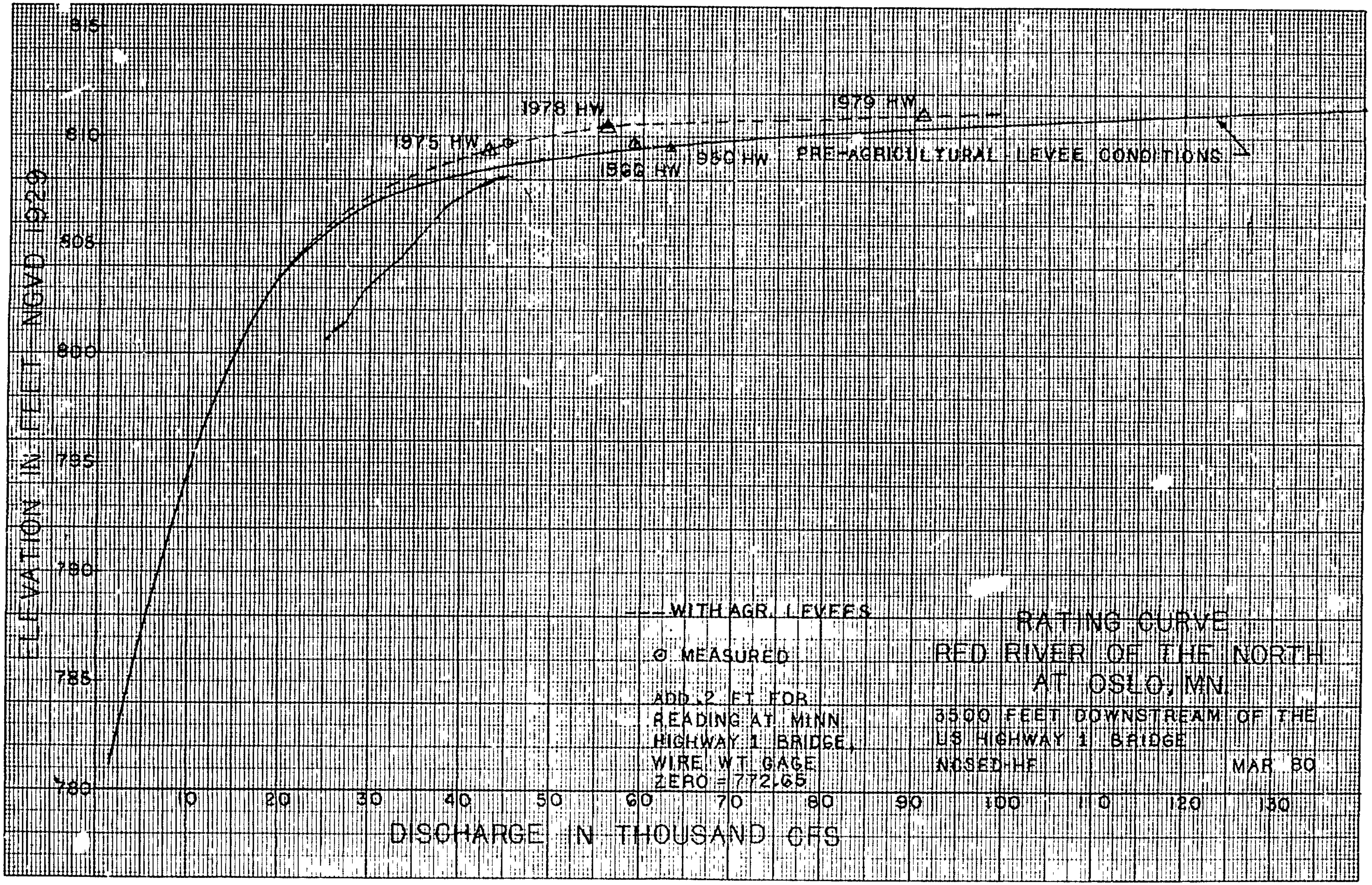


Figure 10 - Rating curve, Red River of the North at Oslo, Minnesota

C. ECONOMIC EVALUATION OF FLOOD DAMAGES

1. Determination of Damages

In June 1981, a massive data collection effort was instituted by the U.S. Army Corps of Engineers to inventory every unit (i.e., structure) in the 100-year floodplain downstream of Grand Forks. Much of this area had been inventoried under subbasin studies but at different times, representing different development conditions. A more uniform base was needed to provide the best possible analysis and assess the impacts of various proposed actions.

a. Residential Damages: Urban - A brief evaluation was conducted for urban areas along the main stem. The average annual existing condition damages are shown below. A detailed hydraulic-economic analysis was not done for these urban areas.

Table 3 - Average annual urban flood damages - existing conditions

Location	Amount
Minnesota	
Noyes	$10,000
Robbin	5,250
St. Vincent	17,500
Oslo	57,260
Total	90,010
North Dakota	
Joliette	60
Bowesmont	3,920
Drayton	8,130
Pembina and South Pembina	173,000
Total	185,110
Total Minnesota and North Dakota	275,120

b. Residential Damages: Nonurban - The areas outside the major cities were divided into six reaches as described in the Technical Notes at the beginning of the report. Each reach was further divided by State.

All residential units were inventoried for these reaches. The inventory includes each structure's market value, ground elevation, first-floor elevation, height of ring levee if present, and river mile reference. A table summarizing some of this information follows.

Table 4 - Summary of inventory data

Reach	Number of residences	Average market value	Number of units with ring levees	Percent of units with ring levees
Minnesota				
1	114	$54,400	0	0
2	161	35,700	24	14.9
3	87	42,100	7	8.0
4	88	37,400	15	17.0
5	65	34,700	11	16.9
6	150	33,100	13	8.7
Subtotal	665	39,300	70	10.5
North Dakota				
1	93	36,600	0	0
2	112	36,100	12	10.7
3	45	36,600	21	46.7
4	53	32,700	17	32.1
5	29	33,100	8	27.6
6	101	37,500	12	11.9
Subtotal	433	36,000	70	16.1
Total	1,098	38,000	140	12.8

A total of 1,098 residential nonurban units are in the study area. Approximately 60 percent are on the Minnesota side of the river; 44 percent are in the two reaches immediately downstream of Grand Forks and East Grand Forks. Approximately 13 percent are protected by individual farm levees. These levees range in height from 0.5 to 8 feet; the majority are approximately 3 feet high.

c. Agricultural Damages - Additional information was collected for each farmstead or grain storage unit. This information includes size of farmstead, type and number of grain storage bins, presence or absence of machinery sheds and the approximate elevation of significant structures. Detailed interviews were conducted with 145 farmers to determine what modifications they made in their operations because of flooding. Their information was combined with information provided by local representatives of the U.S. Department of Agriculture to give crop patterns, yields, and substitute cropping for each reach. Table 5 shows the land use by crop and crop yields for each reach.

Table 5 - Land use by crop and crop yield

Crop	Reach 1 Percent use	Reach 1 Yield	Reach 2 Percent use	Reach 2 Yield	Reach 3 Percent use	Reach 3 Yield	Reach 4 Percent use	Reach 4 Yield	Reach 5 Percent use	Reach 5 Yield	Reach 6 Percent use	Reach 6 Yield
Minnesota												
Wheat	60	47.5 bu	56	47.5 bu	58	47.5 bu	58	47.5 bu	58	47.5 bu	61	47.5 bu
Barley	12	69 bu	16	69 bu	15	62 bu	15	62 bu	15	62 bu	18	62 bu
Sunflowers	3	1,700 lbs	2	1,700 lbs	6	1,500 lbs	6	1,500 lbs	6	1,500 lbs	6	1,500 lbs
Sugar beets	15	17 tons	16	17 tons	7	17 tons	7	17 tons	7	17 tons	4	16 tons
Flax											2	20 bu
Potatoes	2	200 cwt	3	200 cwt								
Pinto beans					6	1,450 lbs	6	1,450 lbs	6	1,450 lbs		
Not cultivated	8		7		8		8		8		9	
North Dakota												
Wheat	39	50 bu	39	50 bu	41	47.5 bu	41	47.5 bu	41	47.5 bu	55	47.5 bu
Barley	16	65 bu	16	65 bu	20	58 bu	20	58 bu	20	58 bu	12	58 bu
Sunflowers	8	1,700 lbs	8	1,700 lbs	5	1,600 lbs	5	1,600 lbs	5	1,600 lbs	13	1,600 lbs
Sugar beets	10	17 tons	10	17 tons	7	16 tons	7	16 tons	7	16 tons	5	16 tons
Flax					3	20 bu	3	20 bu	3	20 bu		
Potatoes	10	200 cwt	10	200 cwt	6	200 cwt	6	200 cwt	6	200 cwt	3	200 cwt
Pinto beans	3	1,500 lbs	3	1,500 lbs	7	1,500 lbs	7	1,500 lbs	7	1,500 lbs	4	1,500 lbs
Not cultivated	14		14		11		11		11		8	

Farmland damage from floods is of two types: (1) crop damage or delay in planting and (2) other agricultural damages.

(1) Crop Damage - A flood will not cause most farmers to change their initial cropping plans until 24 May. Crops planted from mid- to late May will have reduced yields. In some years, cropping has been delayed until June. Substitute crops planted in June are wheat, buckwheat, and flax. Rapeseed is used occasionally. The yields from these crops will also be reduced but will be greater than yields from most other crops in a short growing season.

Because of different cropping patterns and productivity, each reach will have different crop damages. To compare reaches, a "typical" dollar damage figure was derived for each reach. This typical figure takes into account cropping patterns, productivity, long-term price trends (using current normalized prices), and a limited pattern of historic events. These values should not be used to represent any particular event. They illustrate what the average damage per acre would be expressed in constant dollars for a long record of events. Table 6 shows these values.

Table 6 - Average weighted damage per acre (based on limited flood history)

Reach	Damages (dollars per acre)
Minnesota	
1	$58.45
2	105.35
3	72.27
4	65.12
5	64.17
6	51.31
North Dakota	
1	56.90
2	91.73
3	80.61
4	71.48
5	65.93
6	66.26

(2) Other Agricultural Damages - Damages to the noncrop and nonresidential portion of the agricultural sector were determined from information obtained from detailed interviews with farmers. Total damages to other agricultural operations for farms without ring levees were $43.77 per flooded acre. Approximately 70 percent of these damages occurs on farmsteads. The breakdown of damages by category is shown in table 7.

Table 7 - Other agricultural damage categories

Category	Percent
Loss of stored grain and hay	34
Building damage excluding residence	23
Leaching of fertilizer	12
Debris cleanup	7
Soil erosion	7
Weed infestation	6
Evacuation	5
Machinery damage	5
Livestock loss	1
	100

In each reach, some farmsteads are protected by ring levees to various levels of protection. The exact amount of reduction in damages is difficult to determine without a detailed analysis of each unit. Although it would be possible to conduct such an analysis with available information, time constraints are prohibitive. For ease of calculation and analysis, most ring levees are assumed to protect to the level of the 1978 flood. Under this assumption, farmstead damages are estimated to be reduced 80 percent (residual damages would be 20 percent). Therefore, damages for acres which do not incur farmstead damages are $19.26 per acre (($43.77 x 0.30) + ($43.77 x (0.70 x 0.20))). Other agricultural damages for each reach are shown in the following table.

Table 8 - Other agricultural damages (average annual, existing conditions)

Reach	Percent of farmsteads with ring levees	Acres affected by floods: Total	Acres affected by floods: Reduced damages from ring levees (1)	Acres affected by floods: Receiving full damages	Damages: Acres protected by ring levees (2)	Damages: Acres receiving full damages (3)	Damages: Total	Damages per acre (4)
Minnesota								
1	0	290	-	290	-	$12,700	$12,700	$43.77
2	14.9	580	90	490	$1,700	21,400	23,100	40.12
3	8.0	200	20	180	400	7,900	8,300	41.81
4	17.0	1,090	190	900	3,700	39,400	43,100	39.60
5	16.9	4,580	770	3,810	14,800	166,800	181,600	39.62
6	8.7	7,500	650	6,850	12,500	299,800	312,300	41.63
North Dakota								
1	0	320	-	320	-	14,000	14,000	43.77
2	10.7	2,570	270	2,300	5,200	100,700	105,900	39.09
3	46.7	1,660	780	880	15,000	38,500	53,500	32.32
4	32.1	4,300	1,380	2,920	26,600	127,800	154,400	35.90
5	27.6	2,450	310	2,140	6,000	93,700	99,700	40.70
6	11.9	6,400	1,040	5,360	20,000	234,600	254,600	39.80

(1) Using an assumed level of protection. Actually, the protection provided by each existing ring levee will vary depending on their location, construction materials used, construction techniques used, maintenance, etc. Generally, this protection will be considerably less than the assumed level used here.
(2) $19.26 per acre.
(3) $43.77 per acre.
(4) Other agricultural damage per acre excluding farm residence damages. $43.77 per acre adjusted to account for ring levees.

2. Comparison of "Without Levee" Condition with Existing Condition

The following assumptions were made in evaluating damages:

a. All existing ring levees are assumed to be in place and 100 percent effective to top of levee and 100 percent ineffective after they are overtopped.

b. Roads and bridges are assumed to have impacts consistent with their historic impacts.

c. The "without levee" condition assumes that no main stem agricultural levees are in place, and is compared to the computed "with levee" profile.

d. The existing condition assumes main stem levees are as observed in June 1981.

Specific assumptions for each reach are shown below.

a. Agricultural areas

(1) Reach 2, North Dakota - Lowest levee height is 806.1. Levees would be ineffective for the 1975 flood.

(2) Reach 3, North Dakota - Lowest levee height is 807.3. Levee would be ineffective for the 1975 flood.

(3) Reach 2, Minnesota - Levee would be almost 100-percent effective up to the 1978 flood elevation. Overtopping for floods higher than this would be similar to observed relationships.

(4) Reach 3, Minnesota - Lowest levee height is 810.4. Levees would be effective to only slightly greater than the 1978 flood level.

(5) Reach 4, Minnesota - Lowest levee height is 800.5. Rejoins observed curve at that elevation.

b. Residential areas

(1) Reach 2, North Dakota - Levee low spot is at 806.1; until then it is 100-percent effective. Effectiveness gradually decreases; by the 1975 flood level, the levee has no effect.

(2) Reach 3, North Dakota - Levee is effective at elevation 807.3. This elevation is below the zero point of damage. For residential areas, these levees are not effective.

(3) Reach 2, Minnesota - Levees are assumed 100-percent effective for a recurrence of the 1978 flood. Flood damages from a 1979 level are expected to duplicate damages from the 1979 flood (flooded units taken from aerial photos). Levees are assumed ineffective for the 1979 level plus 0.25 foot.

(4) Reach 3, Minnesota - Same assumptions as Reach 2.

(5) Reach 4, Minnesota - Same assumptions as Reach 2.

Figures 11a and 11b show the maximum area flooded in Reaches 1 through 4 for the 1975 summer flood. High-water data were not available for the area downstream of the Highway 317/17 bridge (Reaches 5 and 6). Figures 12a through 12c and 13a through 13c show the maximum flooded area for the 1978 and 1979 spring floods, respectively. The flooded area outlines for these floods are based on aerial photos and interviews with local residents conducted in summer 1981. These figures are generalized flooded area outlines - for specific sites, exceptions to the flooded area shown could occur, and ground elevation at the site would have to be compared to the observed or computed water surface elevation. The "without levee" profiles have also been used to generate estimated outlines of flooded areas for the "without levee" conditions. By comparing the two sets of flooded areas, we can determine the effects of the agricultural levees on flooded area for the 1975, 1978, and 1979 floods. Such a comparison is shown in table 9.

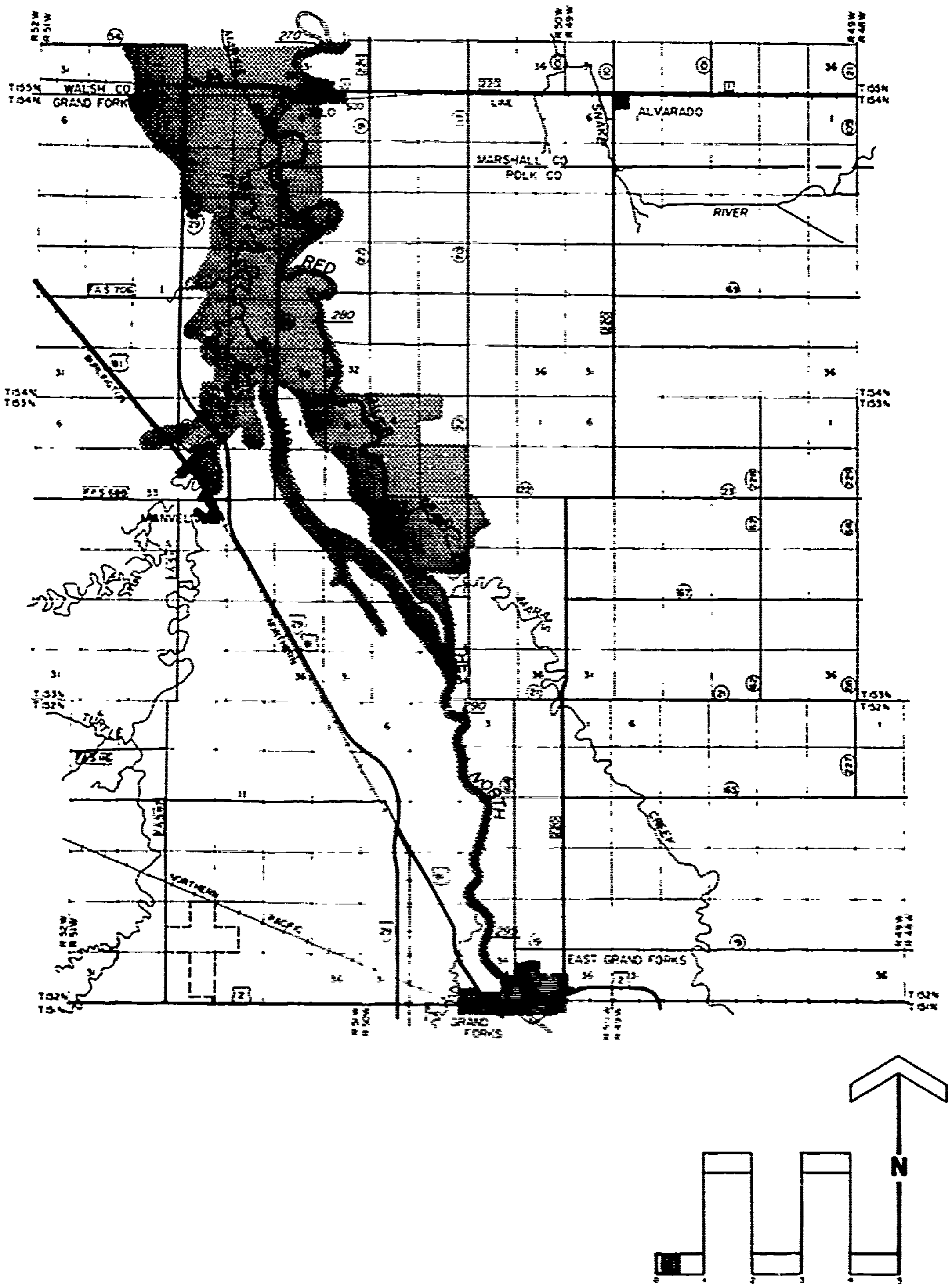


Figure 11a - Maximum area flooded

1975 FLOOD (SUMMER)

RED RIVER MAIN STEM

REACH 1 - REACH 2

RIVER MILE 271 - RIVER MILE 296

OSLO - GRAND FORKS

1981

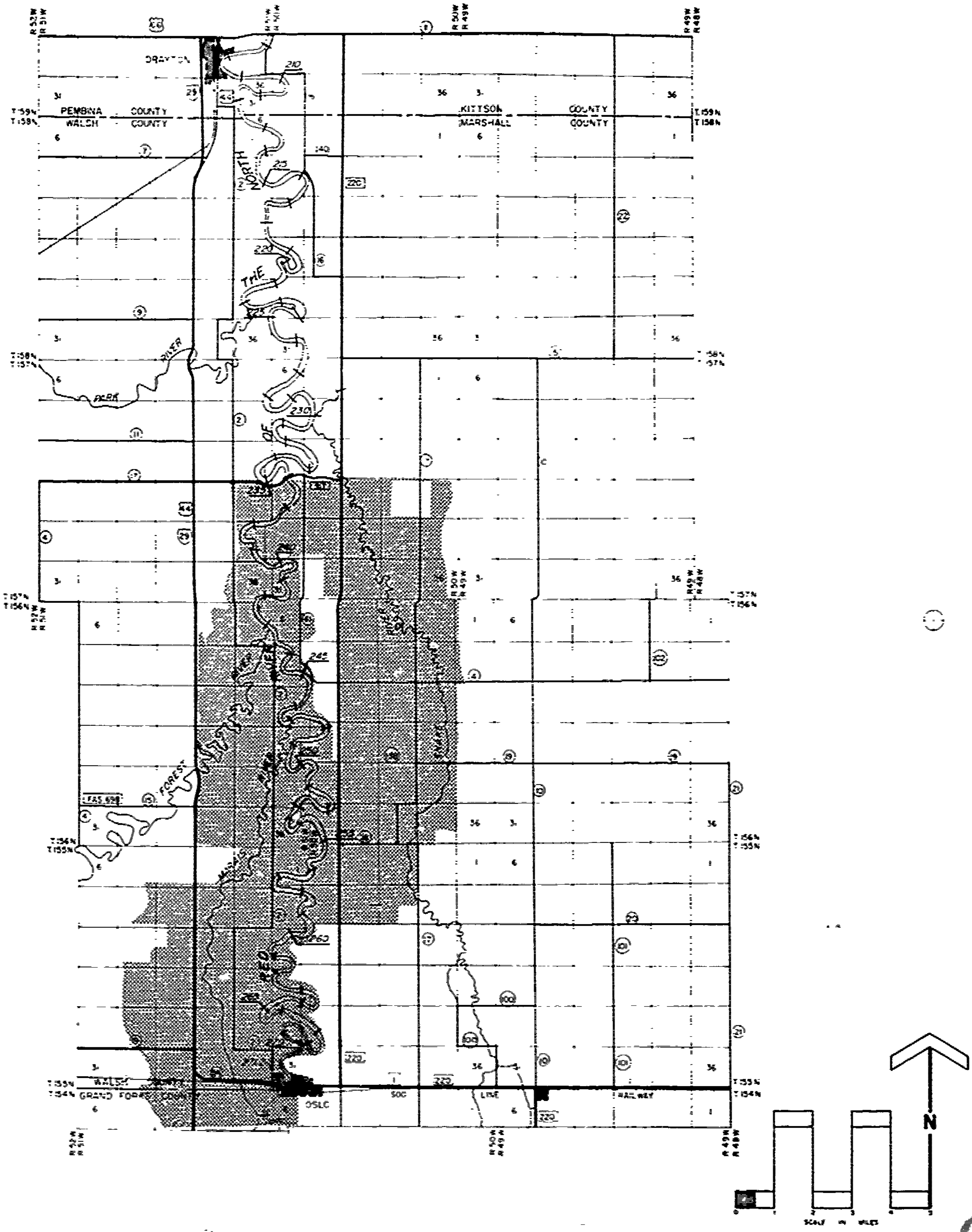


Figure 11b - Maximum area flooded

1975 FLOOD (SUMMER)

RED RIVER MAIN STEM

REACH 3 - REACH 5

RIVER MILE 206 - RIVER MILE 271

DRAYTON - OSLO

1981

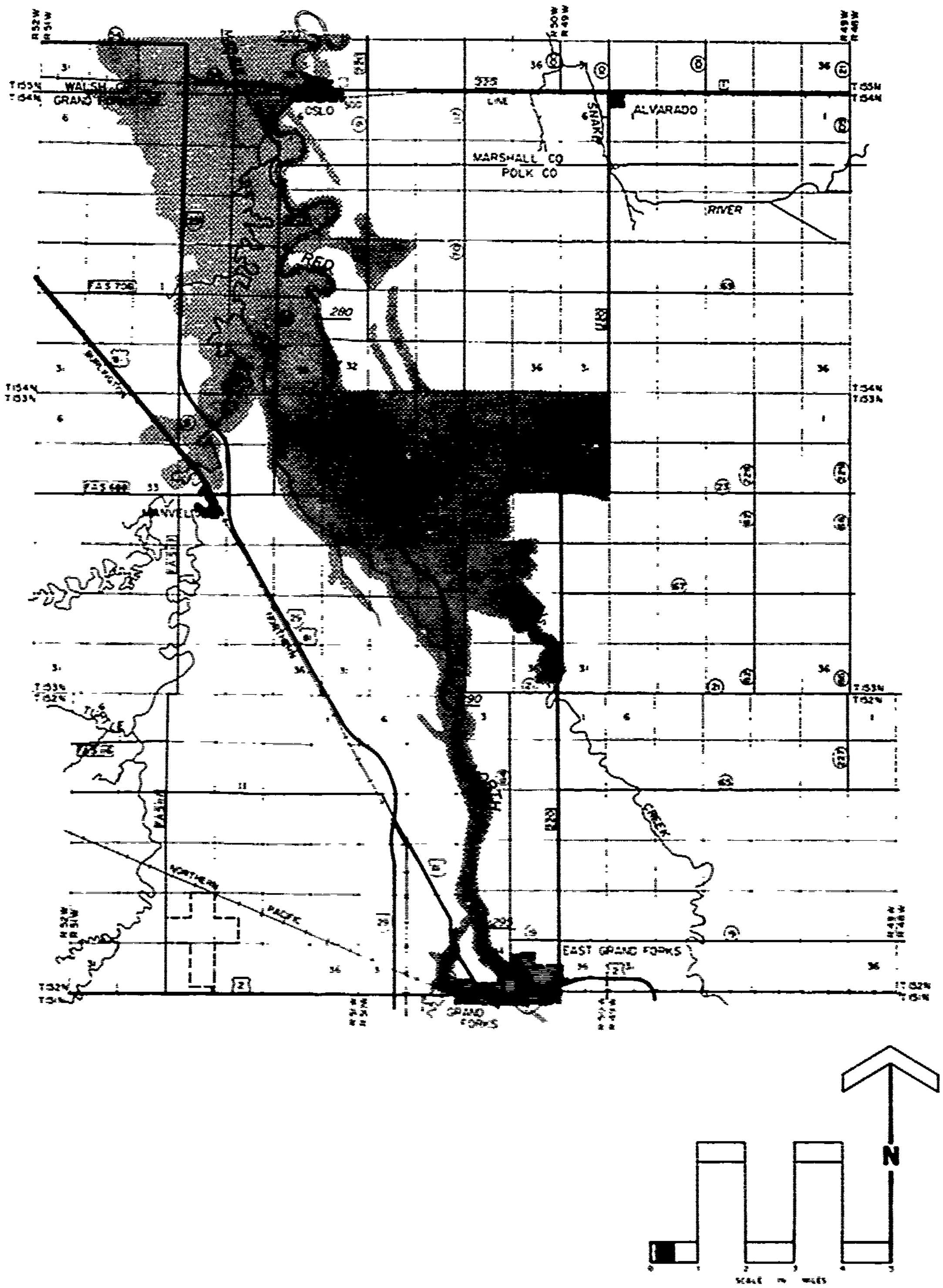


Figure 12a - Maximum area flooded 1978 FLOOD	RED RIVER MAIN STEM REACH I - REACH 2 RIVER MILE 271 - RIVER MILE 296 OSLO - GRAND FORKS 1981

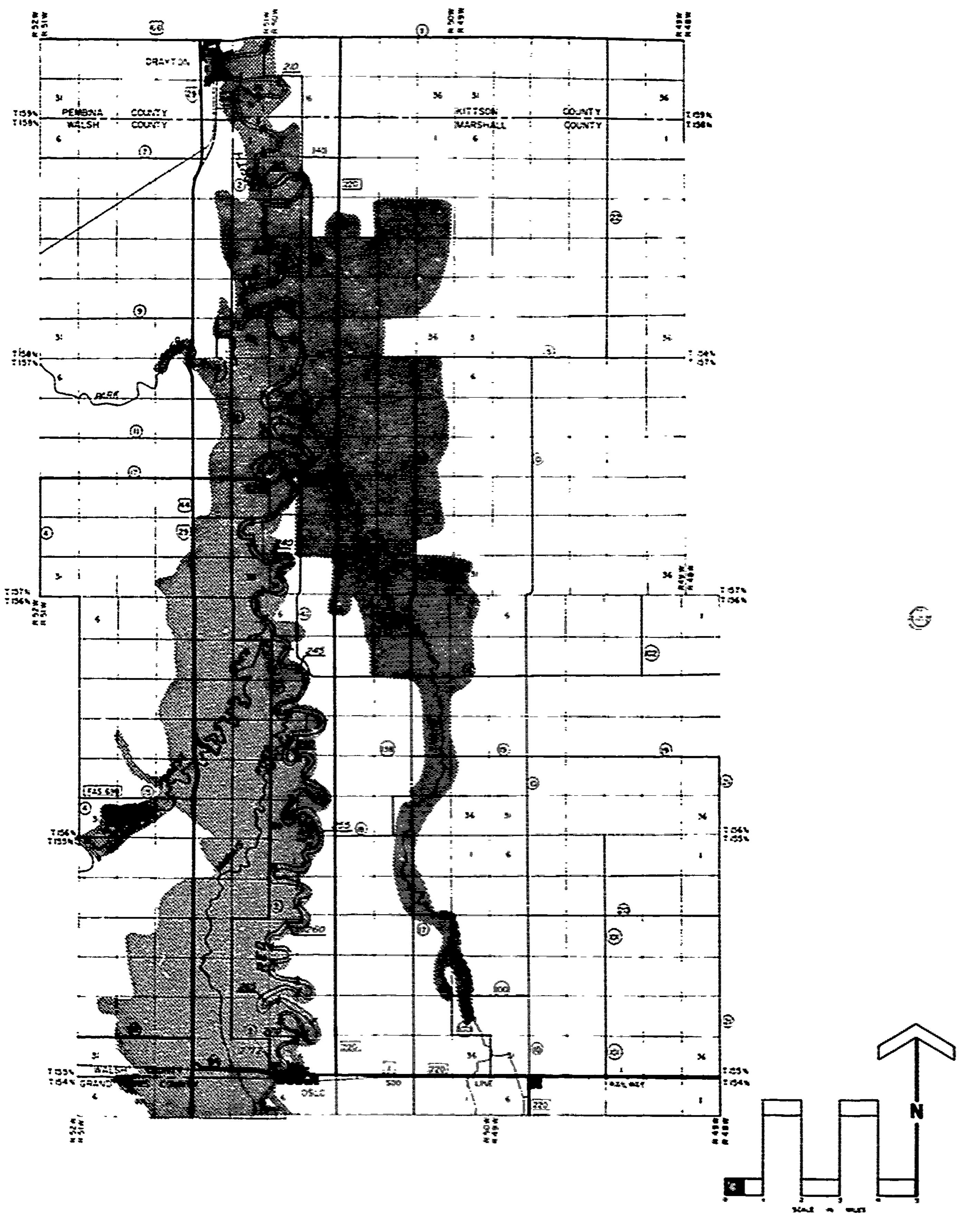


Figure 12b - Maximum area flooded

1978 FLOOD

RED RIVER MAIN STEM
REACH 3 - REACH 5
RIVER MILE 206 - RIVER MILE 271
DRAYTON - OSLO
1981

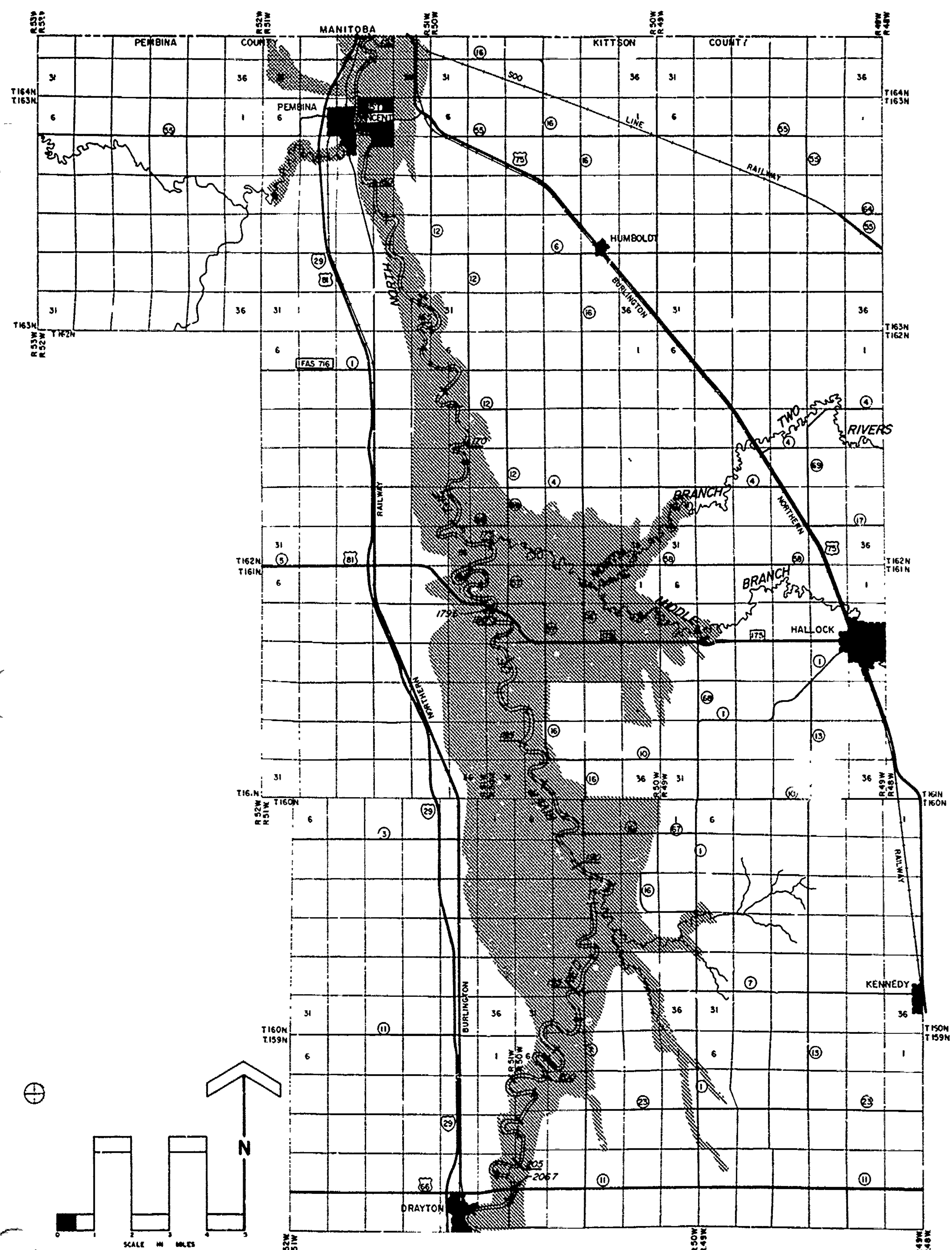
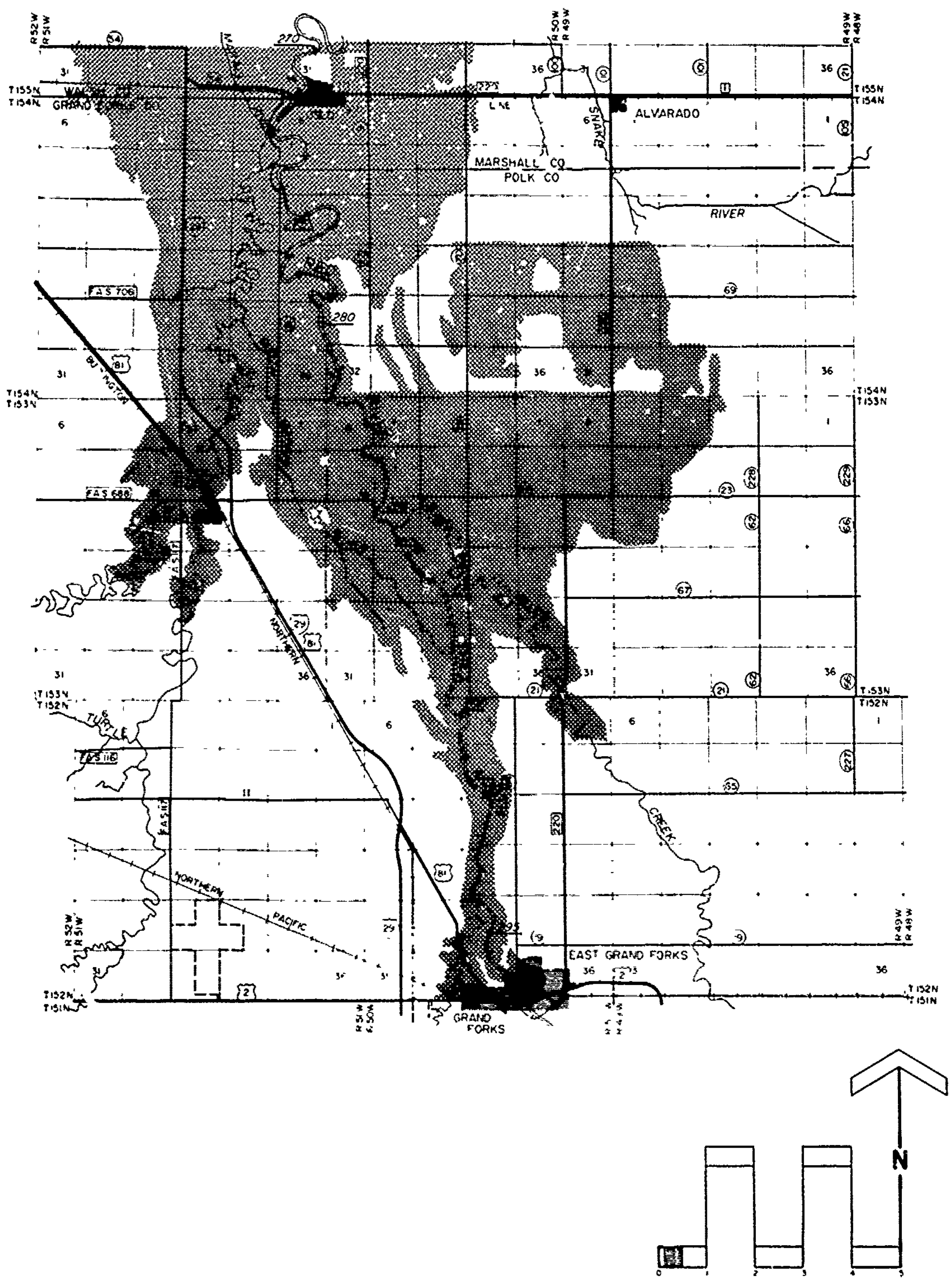


Figure 12c - Maximum area flooded	RED RIVER MAIN STEM
1979 FLOOD	REACH 6
	RIVER MILE 155 - RIVER MILE 206
	INTERNATIONAL BORDER-DRAYTON
	1981



1979 FLOOD

Figure 13a - Maximum area flooded

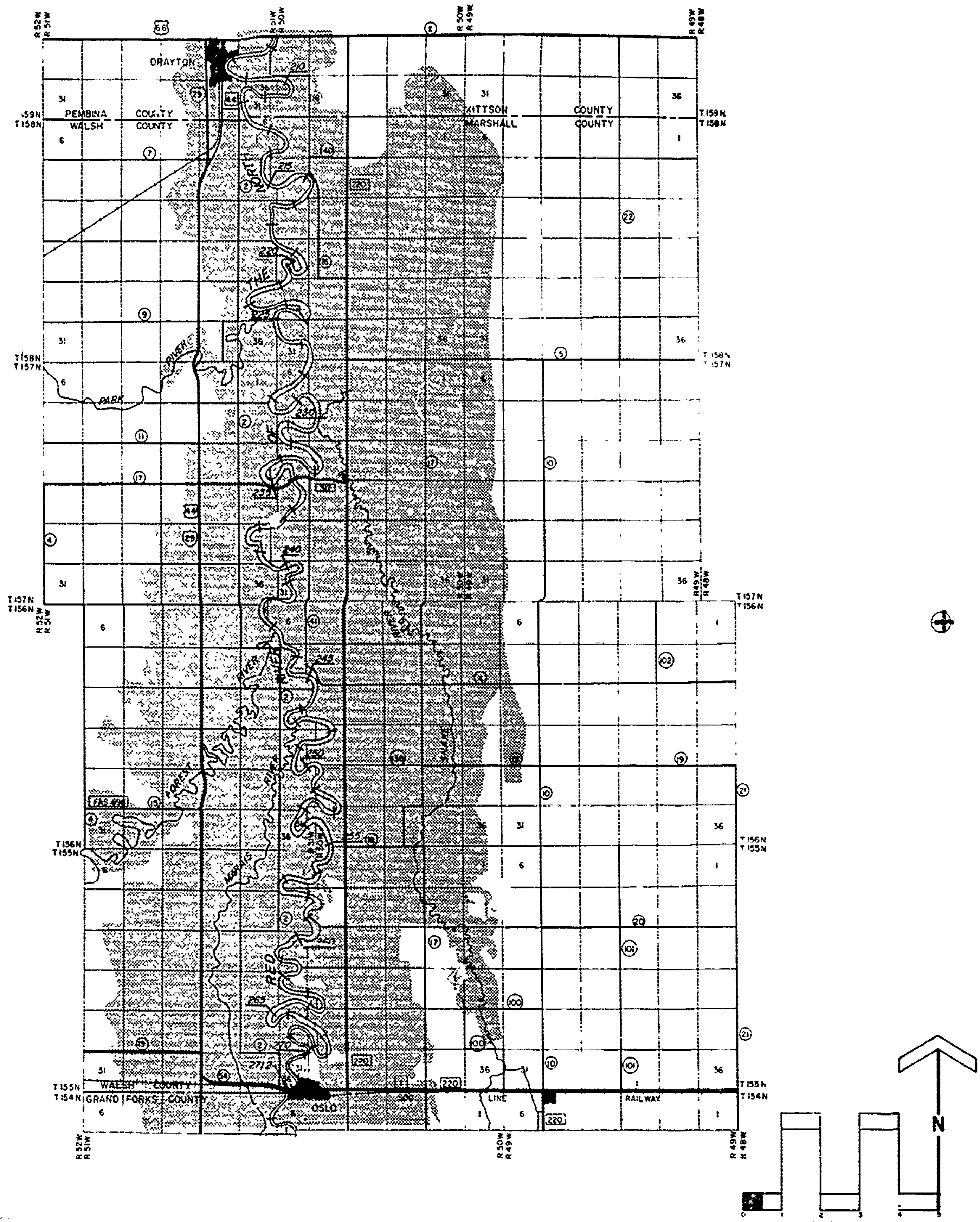
RED RIVER MAIN STEM

REACH 1 - REACH 2

RIVER MILE 271 - RIVER MILE 296

OSLO - GRAND FORKS

1981



1979 FLOOD

Figure 13b - Maximum area flooded

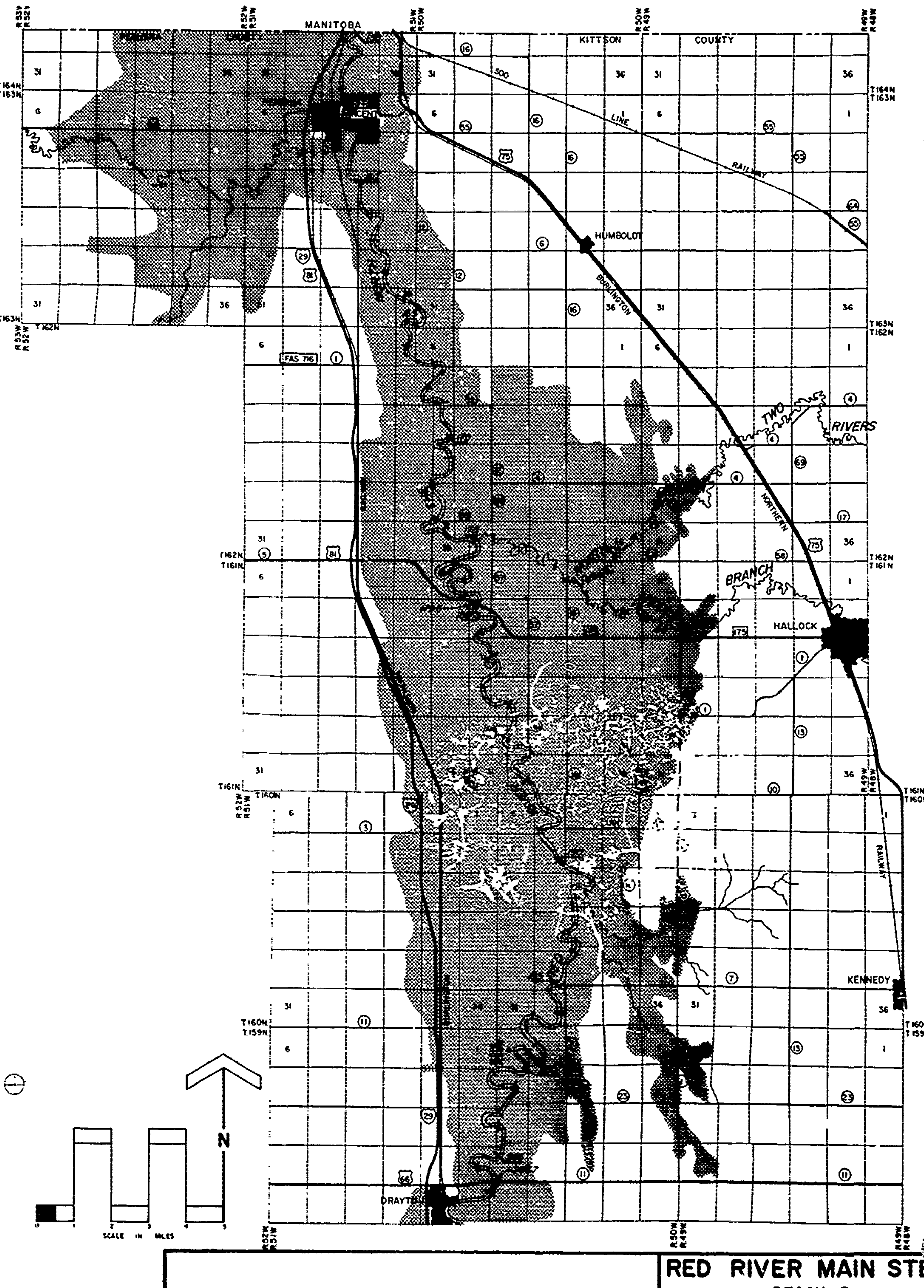
RED RIVER MAIN STEM

REACH 3 - REACH 5

RIVER MILE 206 - RIVER MILE 271

DRAYTON - OSLO

1981



1979 FLOOD

Figure 13c - Maximum area flooded

RED RIVER MAIN STEM
REACH 6
RIVER MILE 155 – RIVER MILE 206
INTERNATIONAL BORDER-DRAYTON
1981

Table 9 - Comparison of flooded areas with and without agricultural levees[1]

Year	State	Flooded area (acres) Without levees	With levees	Net benefit area (acres)
1975	Minnesota	44,010	32,910	11,100
	North Dakota	34,130	38,420	-4,290
1978	Minnesota	55,960	30,740	25,220
	North Dakota	41,210	47,360	-6,150
1979	Minnesota	76,050	73,360	2,690
	North Dakota	59,370	65,160	-5,790

(1) For reaches 2 through 4 only.

Table 10 summarizes the estimated damages for a recurrence of historic floods. All damages are translated to October 1981 price levels. This table can be used to compare damages for specific events; for example, a recurrence of the 1978 flood in Reach 2. In Reach 2, comparative damages can be found by referring to the damages for the specific categories in columns 5 and 8:

Category	Column 5	Column 8	Change
Agricultural			
Minnesota - Reach 2	0 (acres)[3]	17,080 (acres)	17,080 acres benefited
North Dakota - Reach 2	16,200 (acres)	16,130 (acres)	70 acres induced damages
Total			17,010 benefited
Nonurban residential			
Minnesota - Reach 2	0[5]	$191,000	$191,000 benefits
North Dakota - Reach 2	$403,000	248,000	155,000 induced damages
Total			36,000 benefits

The Minnesota damages in column 5 are footnoted. An estimate of damage for failure of these levees is shown in the footnotes to table 10.

Similar comparisons for all reaches can be made using columns 5 and 8 for the 1978 flood and columns 6 and 9 for the 1979 flood.

Dollar damages are not provided for agricultural lands for specific events. A more detailed analysis of 1979 and 1980 actual crop expenditures and prices would be needed.

Table 10 - Estimated damages for recurrences of historic floods

Reach	No levee, zero dam elevation	No levee, 1950 flood	Existing condition (with levees) 1975 (summer)(1) Observed	Existing condition (with levees) 1975 (summer)(1) Existing	Existing condition (with levees) 1978	Existing condition (with levees) 1979	"Without levees" condition 1975	"Without levees" condition 1978	"Without levees" condition 1979
	1	2	3	4	5	6	7	8	9
AGRICULTURAL				Acres(2)					
Minnesota									
1	808.8	N/A	570	570	2,370	5,010	570	2,370	4,450
2	797.2	N/A	5,400	0	0(3)	28,430	12,030	17,080	33,660
3	797.2	N/A	5,060	0	0(3)	15,220	9,090	12,830	13,970
4	786.0	N/A	22,450	0	0(3)	29,710	22,890	26,050	28,420
5	785.5	N/A	0	0	19,790	33,000	0	19,790	33,040
6	785.5	N/A	0	0	33,600	59,960	0	33,600	59,960
Subtotal			33,480		55,760	171,330	44,580	111,720	173,500
North Dakota									
1	808.8	N/A	930	930	1,890	3,780	930	1,890	3,780
2	797.2	N/A	13,470		16,200	23,700	13,220	16,130	23,260
3	797.2	N/A	13,140		14,000	18,070	10,380	11,350	15,960
4	786.0	N/A	11,810		17,160	23,390	10,530	13,730	20,150
5	785.5	N/A	0	0	9,010	15,250	0	9,000	15,250
6	785.5	N/A	0	0	23,410	66,210	0	23,410	66,210
Subtotal			39,350		81,670	150,400	35,060	75,510	144,610
Total			72,830		137,430	321,730	79,640	187,230	318,110
				Damages					
NONURBAN RESIDENTIAL(4)									
Minnesota									
1	800.1	$135,000	$52,000	$54,000	$227,000	$465,000	$54,000	$132,000	$388,000
2	806.8	284,000	129,000	0(5)	0(5)	291,000(6)	93,000	191,000	457,000
3	804.0	872,000	509,000	0(5)	0(5)	315,000(6)	443,000	591,000	924,000
4	795.6	1,309,000	500,600	0(5)	0(5)	753,000(6)	257,000	401,000	742,000
5	790.7	563,000	79,000	79,000	156,000	397,000	79,000	156,000	397,000
6	788.5	801,000	118,000	118,000	258,000	786,000	118,000	258,000	786,000
Subtotal		3,964,000	1,387,600	251,000	641,000	3,007,000	1,044,000	1,729,000	3,694,000
North Dakota									
1	819.7	68,000	3,000	3,000	78,000	323,000	3,000	73,000	283,000
2	804.0	352,000	219,000	171,000	403,000	758,000	114,000	248,000	503,000
3	807.8	207,000	135,000	147,000	222,000	348,000	113,000	167,000	273,000
4	795.0	420,000	116,000	122,000	181,000	326,000	43,000	92,000	190,000
5	794.5	98,000	0	0	14,000	70,000	0	14,000	70,000
6	791.8	335,000	2,000	2,000	18,000	288,000	2,000	18,000	288,000
Subtotal		1,480,000	475,000	445,000	916,000	2,113,000	275,000	612,000	1,607,000
Total		5,444,000	1,862,600	696,000	1,557,000	5,120,000	1,319,000	2,341,000	5,301,000

(1) The hydraulic model provides a water surface profile for 1975 flow (existing conditions) that is slightly lower at a number of the ungaged points than the observed 1975 flow profile. While this difference is not significant in terms of the hydraulic model, the greater sensitivity of the economic model yields lower damages for the lower water surface elevations.

(2) Method of estimating acres is not sensitive to small changes in elevation.

(3) Agricultural levees would be effective for 1978 discharges and elevations. Actual area flooded in 1978, principally from tributary flooding behind the levees, was 11,270 (Reach 2), 3,490 (Reach 3), and 15,980 (Reach 4).

(4) Includes residences on farmsteads.

(5) Agricultural levees are effective for the 1975 and 1978 flood elevations. If the levees totally failed, damages under existing conditions for 1975 and 1978 would be:

	Reach 2	Reach 3	Reach 4
1975 flood	$107,000	$589,000	$364,000
1978 flood	352,000	1,031,000	827,000

(6) Damages sustained by units with totally ineffective levees are $684,000, $1,255,000 and $1,144,000 for Reaches 2, 3, and 4, respectively (identified from aerial photos).

Table 11 summarizes the differences between the "without levee" condition and existing conditions. Damages are combined with the frequency analysis to give damages on an average annual basis. The numbers in parentheses are disbenefits or induced damages. Footnote 2 explains why no benefits are recorded in North Dakota agricultural Reaches 2 and 3. Benefits in those reaches would probably be greater if the Minnesota levees had not resulted in higher stages. The damage per acre figure in table 11 represents both crop damage and other agricultural damage, and as such is the sum of the last columns of tables 6 and 8.

Table 11 - Comparison of average annual damages - "without levee" vs. existing conditions

Reach	Damage per acre	Without levees Acres	Without levees Damages	Existing conditions Acres	Existing conditions Damages	Benefits of levees(1) Acres	Benefits of levees(1) Dollars
AGRICULTURAL							
Minnesota							
1	$102.22	290	$29,644	290	$29,644	0	0
2	145.47	4,380	637,158	580	84,373	3,800	$552,786
3	114.08	3,340	381,027	200	22,816	3,140	358,211
4	104.72	9,150	958,188	1,090	114,145	8,060	844,043
5	103.79	4,580	475,358	4,580	475,358	0	0
6	92.94	7,500	697,050	7,500	697,050	0	0
Subtotal		29,240	3,178,425	14,240	1,423,386	15,000	1,755,040
North Dakota							
1	100.67	320	32,214	320	32,214	0	0
2	130.82	4,520	591,306	2,570(2)	336,207	1,950	255,099
3	112.93	3,750	423,488	1,660(2)	187,464	2,090	236,024
4	107.38	4,070	437,037	4,300	461,734	(230)	(24,697)
5	106.63	2,450	261,244	2,450	261,244	0	0
6	106.06	6,390	677,723	6,390	677,723	0	0
Subtotal		21,500	2,423,012	17,690	1,956,586	3,810	466,426
Total		50,740	5,601,437	31,930	3,379,972	18,810	2,221,466
NONURBAN RESIDENTIAL							
Minnesota							
1			21,100		26,000		(4,900)
2			22,100		2,200		19,900
3			97,900		2,700		95,200
4			69,500		27,000		42,500
5			30,700		30,700		0
6			54,300		54,300		0
Subtotal			295,600		142,900		152,700
North Dakota							
1			12,700		13,500		(800)
2			34,100		40,900		(6,800)
3			17,300		24,900		(7,600)
4			15,800		29,800		(14,000)
5			2,900		2,900		0
6			10,700		10,700		0
Subtotal			93,500		122,700		(29,200)
Total			389,100		265,600		123,500

(1) Numbers in parentheses are negative or induced damages.

(2) Although the existing condition water surface profile is higher than the "without levee" profile, the low level agricultural levees on the North Dakota side provide substantial benefits.

D. HYDROLOGIC EFFECTS OF EXISTING AND PROPOSED AGRICULTURAL LEVEES

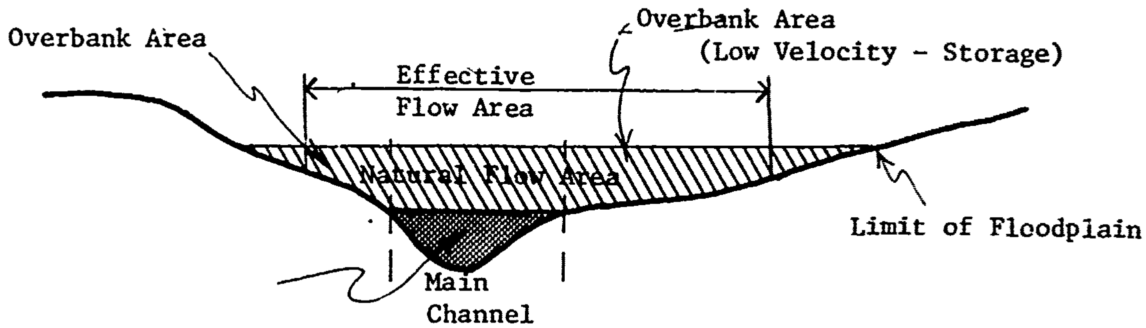
In addition to the obvious increases in flood stages, one of the principal concerns about the agricultural levees is the potential for increased flood flows on the Red River. Agricultural levees encroach into the floodplain, eliminating some of the normal overbank effective flow area. Under natural conditions (without levees), the flow velocities and volumes in these overbank areas are so much less than those in the main channel that the floodwaters can be considered to be effectively in storage. Loss of part or all of this storage area caused by the agricultural levees forces more water into the channel area between the levees, increasing flows, velocities, and stages of floods (figure 14).

This concept of floodplain storage can also be illustrated by a simple analogy - consider that each section of land in the overbank area acts as a small reservoir, storing a quantity of floodwater. Flood flows have a tendency to increase downstream as a result of tributary inflows and local runoff and a tendency to decrease downstream as a result of channel and floodplain storage. Under natural conditions, these factors roughly balance on the Red River of the North, and the peak discharges at Emerson, Manitoba, are typically 10 to 20 percent greater than at Grand Forks. Encroachment on the storage area reduces or eliminates the effect of these small "reservoirs" in the overbank areas, and the water that is no longer in storage contributes to increased downstream flows. With the reduction in floodplain storage, the tendency for flow to increase downstream predominates, and flows at Emerson could be significantly increases.

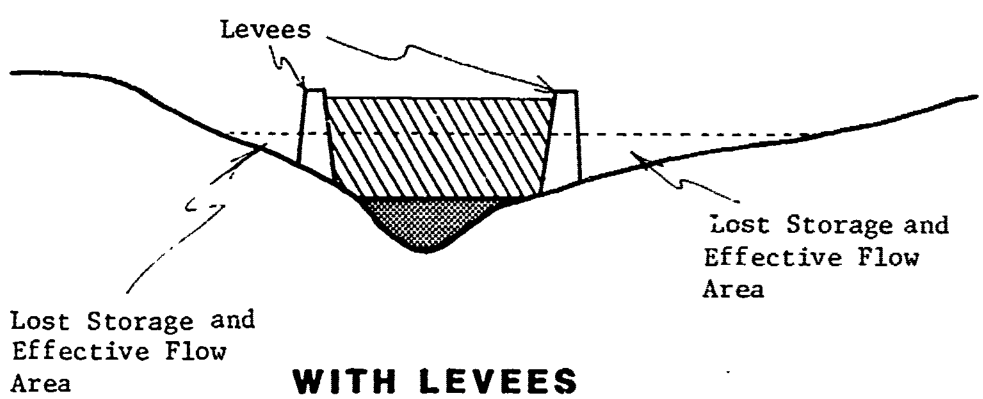
To determine what effect a loss of floodplain storage and effective flow area has on flows, the Corps undertook a sensitivity analysis using the HEC-5 high-flow computer model. The following two encroachment conditions were analyzed:

1. Encroachments that limit the 100-year flood to a 0.5-foot raise as required by the States' criteria (the same as the "100-year levee" setback and floodway alignment).

2. Encroachments that limit flows to the channel area (approximately the same alignment followed by the existing levees).



WITHOUT LEVEES



WITH LEVEES

FLOODPLAIN STORAGE

Figure 14

These two conditions were compared with a condition of no encroachment or "without levee" floodplain condition. Historical flow data from the 1948, 1950, 1965, 1966, 1969, 1975, and 1979 floods were used. The encroachments were considered to be continuous from Grand Forks to Emerson, with no encroachment south of Grand Forks or on the tributaries. Flows of similar magnitude such as the 1966 and 1969 floods at Oslo can cause different flow increase percentages as a result of variations in volumes and timings of tributary flows. Thus, a large range of flow increases is possible depending on tributary inflows. Results of the sensitivity analysis for several locations along the main stem are presented in table 12.

Table 12 - Calculated flow increases (compared to no levee condition)

	Flow increase (in percent)					
	Condition 1			Condition 2		
Station	Average	Low	High	Average	Low	High
Oslo	2	0	5	6	0	13
Mouth of the Forest River	2	0	3	9	1	15
Mouth of the Snake River	2	0	3	11	2	18
Mouth of the Park River	3	0	4	14	2	25
Drayton	2	0	3	16	3	27
Emerson	2	1	3	27	17	36

Condition 1 shows an average increase of 2.3 percent at Emerson. This figure is less than the accuracy of the basic flow data (±5 percent) from the gage readings; therefore, it is very likely that no change in flow could be detected if the States' criteria were followed. On the other hand, condition 2 gives a good example of the additive effects as flow moves downstream. It also shows how changes upstream can create problems downstream. Because the encroachments are as close to the river channel as possible, the change in flow is the worst that could be seen. The potential for flow increases at Emerson exceeds 30 percent with uncontrolled levee construction.

Finally, as a part of this analysis, the impact of levees with the existing levee alignment but assuming a vertical wall of infinite height was also examined. The reach of existing levees is short enough that no significant (i.e., greater than 5-percent) flow increases would be seen at Emerson because adequate floodplain storage is regained downstream of the levees. Also, the complete overtopping of the North Dakota levees in the 1978 and 1979 floods and the partial overtopping of the Minnesota levees in 1979 seemed to restore some of the lost floodplain storage during those two floods. A similar lack of significant hydrologic effects would be expected for any proposed modifications as long as they are confined to the reach of existing levees.

Details related to development of the HEC-5 high-flow hydrologic model can be found in the "River Model Evaluation" report for the International Souris-Red Engineering Board, September 1981.

E. PROPOSED MODIFICATIONS TO EXISTING AGRICULTURAL LEVEES

When the criteria were signed into law in early 1980 by the States of Minnesota and North Dakota, the Governors instructed the local water management agencies to develop a corrective plan for bringing the existing agricultural levees into substantial compliance with the criteria. An informal working group - composed of representatives of the Minnesota Department of Natural Resources, North Dakota State Water Commission, Middle River-Snake River Watershed District, Grand Forks County Water Management Board, and Walsh County Water Management Board - has examined a large number of alternatives for modifying the existing levees. The Corps has provided technical assistance to this working group.

The following section discusses all alternatives considered by the group. The profiles of the various cases are printed on transparency material to facilitiate comparison with each other and with the profiles of the existing levee top elevations (figure 15) and the historic floods (figure 16). The various alternatives relate either to a specific flow (e.g., 35,000 cfs or 43,000 cfs) or to the high-water profile of a specific flood (e.g., 1975 flood profile plus 1 foot). Because the levees were originally constructed to protect against the 1975 summer flood, which had a peak discharge of 43,000 cfs at Oslo, this flood served as a starting point for many of the alternatives.

Different levee alignments were also evaluated for many of the alternatives. The four levee alignments considered are described below in table 13.

Table 13 - Key to levee alignments

Alignment	Minnesota levees	North Dakota levees
A	Existing - 1979 conditions.	Existing - 1979 conditions.
B	Similar to Alignment A, but with equal setback levees in those locations that have levees on only one side of the river.	Similar to Alignment A, but with equal setback levees in those locations that have levees on only one side of the river.
C	Similar to Alignment B, but with some straightening of the levee alignment where existing levees closely follow the meander loops of the river.	Similar to Alignment B, but with some straightening of the levee alignment where existing levees closely follow the meander loops of the river.
D	Alignment C.	Alignment A.

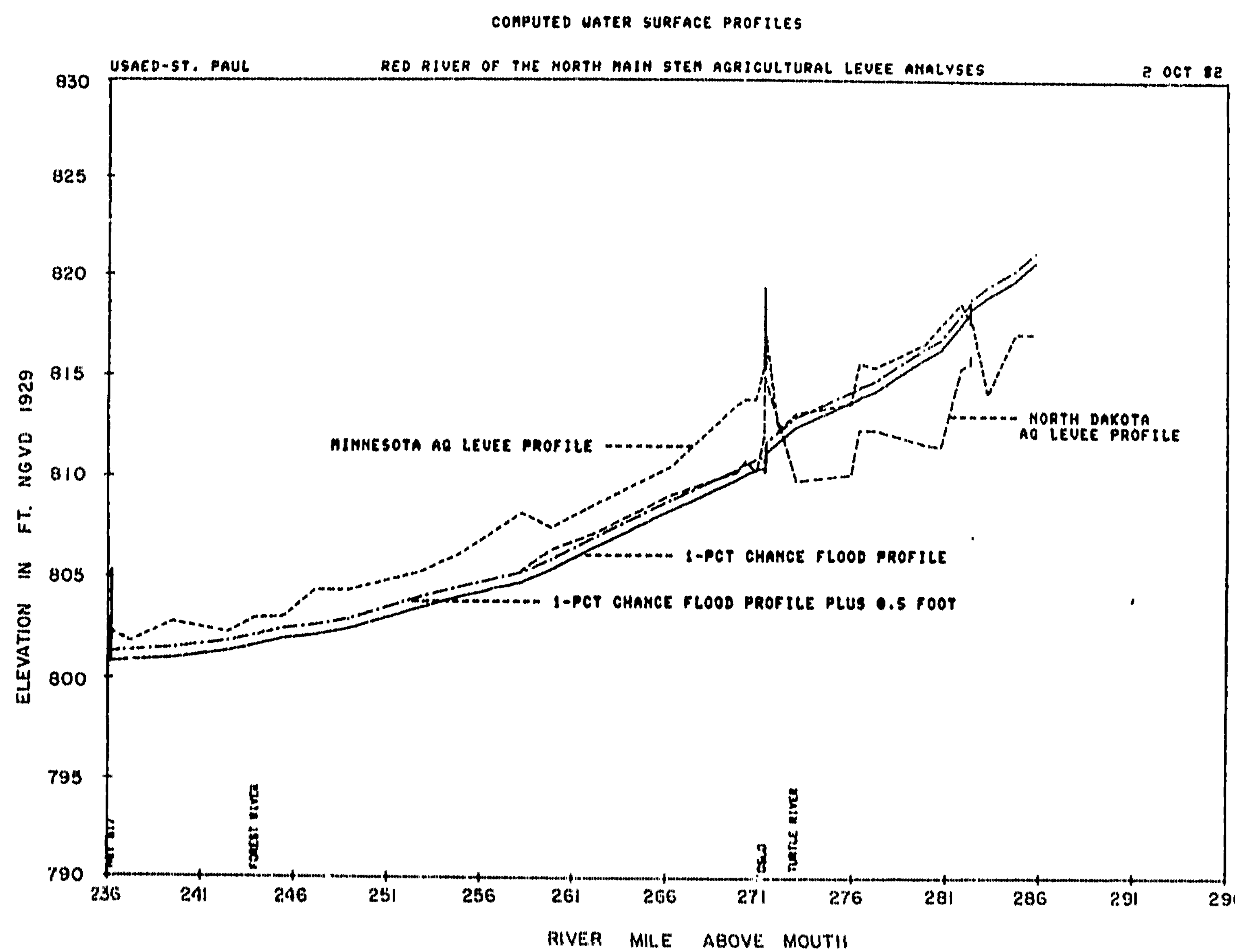


Figure 15 - Profile of existing levee top elevations and water surface profiles for the 1-percent chance flood and 1-percent chance flood + 0.5 foot (States' criteria)

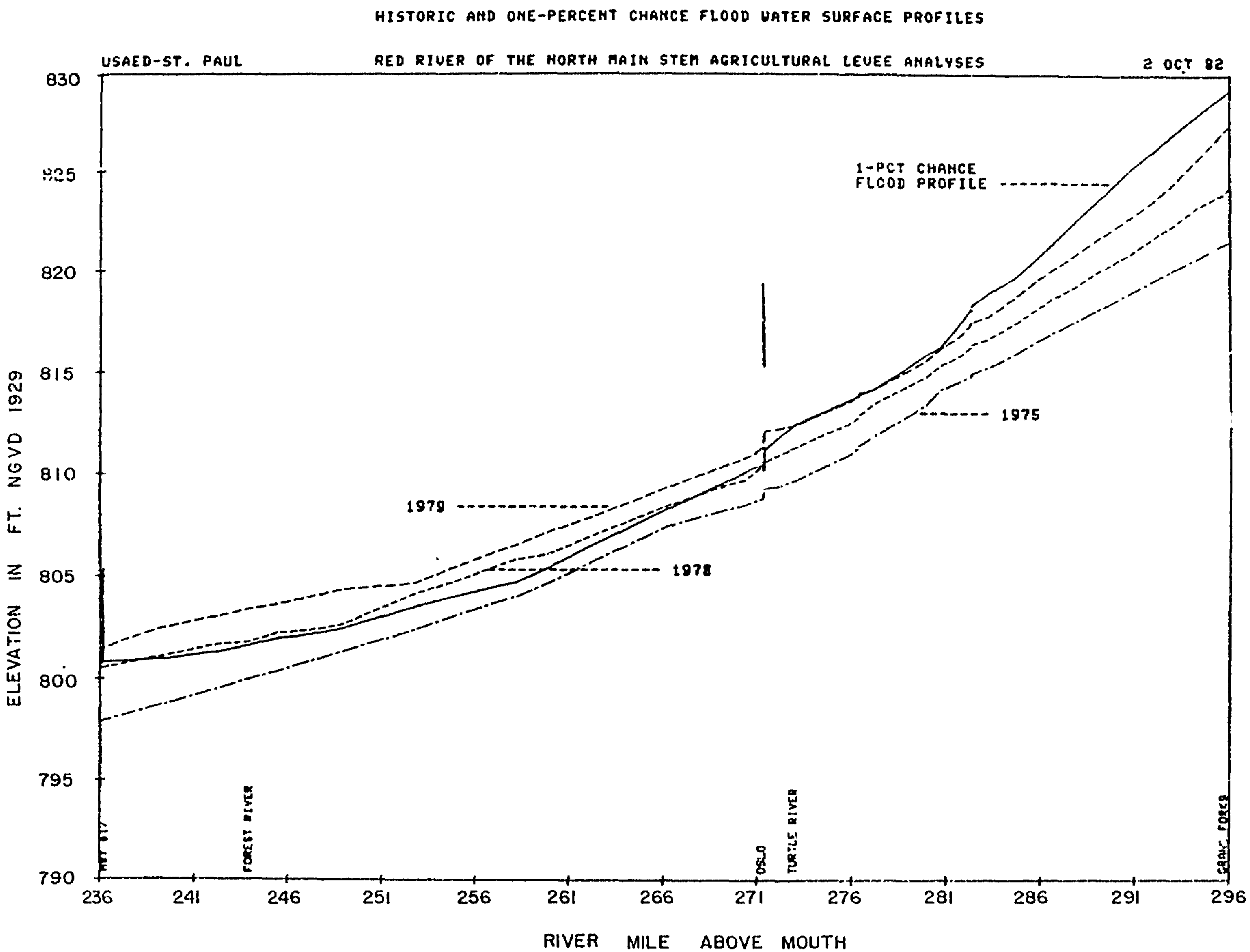


Figure 16 - Profiles of historic floods and the 1-percent chance flood profile

Alignment B involves construction of approximately 5 1/2 miles of new levee on the Minnesota side and 18 1/2 miles of new levee on the North Dakota side. Alignment C represents both removal of existing levees (22 1/2 miles of Minnesota levee and 12 miles of North Dakota levee) and construction of new levees (17 miles on the Minnesota side and 9 1/2 miles on the North Dakota side). Specific details of this alignment are not important. The purpose of analyzing Alignment C is to determine whether a significant stage reduction can be achieved by a modest amount of realignment. In this example, roughly 60 percent of the existing levees are realigned. A lesser or greater degree of realignment could ultimately be chosen by the local boards.

For all of the cases that involve overtopping of the agricultural levees, the X3 option of the HEC-2 model was used. This option assumes no effective flow landward of and below the top elevation of the levees. The assumption about flow inherent in the X3 option is pictured below in figure 17. The X3 option analysis is as agreed upon by the States and local agencies. This method is considered a simplified method of analysis; more detailed analysis using a more sophisticated method is not warranted.

Diagram of X3 Option

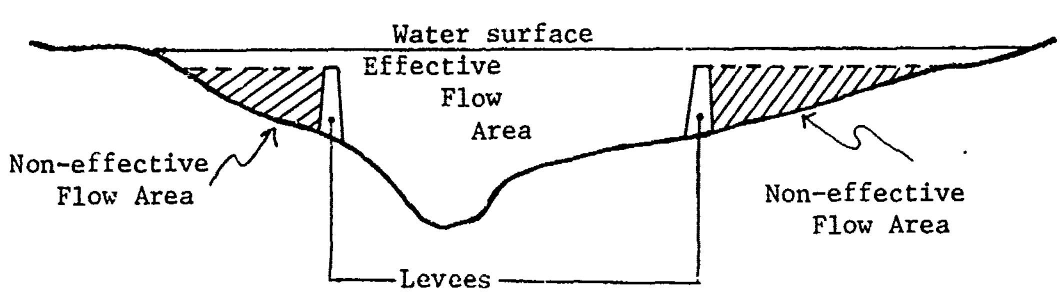


Figure 17

Overtopping analysis using the X3 option is consistent with the States' criteria, which specify "total encroachment" on both sides of the river. In reality, however, these overbank areas are at least partially effective in conveying flows so that the X3 option results in approximate computed water surface elevations. The observed stage in an actual flood that overtopped the levees could be lower than the stage calculated by the model using the X3 option. While the X3 option provides a conservative evaluation of levee overtopping, we feel that its use is justified for three reasons:

1. It is consistent with the "total encroachment" assumption in the States' criteria. If the overbank areas landward of the levees were assumed totally effective in conveying flood flows, or at least partially effective under present conditions, it could become necessary to regulate changes such as road raises in these areas to ensure that the present conveyance is maintained. Such regulations may become necessary in any event.

2. With the exception of Case 0 (i.e., lowering of levees along the existing alignment), none of the cases examined strictly meet the States' criteria. The Minnesota Department of Natural Resources and North Dakota State Water Commission have held the position that any reasonable compromise plan agreed to by the local water management organizations could exceed the criteria by a modest amount (i.e., cause an increase of over one-half foot in the stage of the 1-percent flood). Therefore a precise evaluation of the effect of overtopped agricultural levees on the stage of the 1-percent chance flood becomes less critical.

3. The X3 option provides a valid means of comparing the relative impacts of the various cases on the 1-percent chance flood.

A summary table (table 14) describes discharges and the levee conditions represented by Cases 0 through 41. This table assumes no freeboard on the levees. Corps levee criteria normally specify 2 feet of freeboard for agricultural levees to allow for factors which cannot be rationally accounted for in the design computations. These factors include errors in profile computations, dynamic effects and short-period discharge fluctuations, and flow retardance by debris and ice.

Table 14 - Summary table for proposed modifications

Case Number	Discharge in cfs	Levee Alignment	Minnesota Levee Condition*	North Dakota Levee Condition*	Notes
0	1% chance flood	A	Overtopped	Overtopped	Profile 1.6 feet below 1% chance flood is top of levee necessary to meet criteria.
1	43,000	-	None	None	-
2	43,000	A	Totally effective	Totally effective	Top of levees necessary to contain 43,000 cfs.
3	43,000	B	Totally effective	Totally effective	Top of levees necessary to contain 43,000 cfs.
4	43,000	C	Totally effective	Totally effective	Top of levees necessary to contain 43,000 cfs.
5	1% chance flood	A	Overtopped	Overtopped	Levees as in Case 2.
6	1% chance flood	B	Overtopped	Overtopped	Levees as in Case 3.
7	1% chance flood	C	Overtopped	Overtopped	Levees as in Case 4.
8	39,000	A	Overtopped	Overtopped	Top of levee equal to 1975 HW. Flow computed to yield maximum stage 1/2 foot above level of 1% chance flood.
9	32,500	B	Overtopped	Overtopped	Top of levee equal to 1975 HW. Flow computed to yield maximum stage 1/2 foot above level of 1% chance flood.
10	34,500	C	Overtopped	Overtopped	Top of levee equal to 1975 HW. Flow computed to yield maximum stage 1/2 foot above level of 1% chance flood.
11	1% chance flood	A	Overtopped	Overtopped	Top of levee equal to 1975 HW.
12	1% chance flood	B	Overtopped	Overtopped	Top of levee equal to 1975 HW.
13	1% chance flood	C	Overtopped	Overtopped	Top of levee equal to 1975 HW.

* The "X3" option (assuming no effective flow landward of and below the top of levee elevation) was used for all cases that involve levee overtopping, with the exception of Case 0. Also, no levee freeboard is assumed.

Case Number	Discharge in cfs	Levee Alignment	Minnesota Levee Condition*	North Dakota Levee Condition*	Notes
14	1% chance flood	A	Overtopped	Overtopped	Top of levee equal to 1975 HW + 1 1/2 feet.
15	1% chance flood	B	Overtopped	Overtopped	Top of levee equal to 1975 HW + 1 1/2 feet.
16	1% chance flood	C	Overtopped	Overtopped	Top of levee equal to 1975 HW + 1 1/2 feet.
17	43,000	A	Totally effective	Existing-overtopped	Top of MN levees necessary to contain 43,000 cfs.
18	1% chance flood	A	None	Existing-overtopped	Existing ND levees alone exceed criteria.
19	43,000	A	Overtopped	Overtopped	Top of levee equal to 1975 HW.
20	43,000	B	Overtopped	Overtopped	Top of levee equal to 1975 HW.
21	43,000	C	Overtopped	Overtopped	Top of levee equal to 1975 HW.
22	30,000-40,000	B	Totally effective	Totally effective	Multiple-profile runs.
23	30,000-40,000	C	Totally effective	Totally effective	Multiple-profile runs.

* The "X3" option (assuming no effective flow landward of and below the top of levee elevation) was used for all cases that involve levee overtopping, with the exception of Case 0.

Case Number	Discharge in cfs	Levee Alignment	Minnesota Levee Condition*	North Dakota Levee Condition*	Notes
24	27,000	A	Totally effective	Totally effective	Top of levee equal to 1975 HW. Flow is maximum capacity of levee system before overtopping.
25	26,000	B	Totally effective	Totally effective	Top of levee equal to 1975 HW. Flow is maximum capacity of levee system before overtopping.
26	26,500	C	Totally effective	Totally effective	Top of levee equal to 1975 HW. Flow is maximum capacity of levee system before overtopping.
27	30,500	A	Totally effective	Totally effective	Top of levee equal to 1975 HW + 1 foot. Flow is maximum capacity of levee system before overtopping.
28	30,000-50,000	A	Totally effective	Totally effective	Multiple-profile runs.
29	43,000	A	Totally effective	None	Top of MN levee necessary to contain 43,000 cfs.
30	35,000	A	Totally effective	Existing-overtopped	Top of MN levee necessary to contain 35,000 cfs.
31	35,000	A	Totally effective	None	Top of MN levee necessary to contain 35,000 cfs.
32	35,000	C	Totally effective	Totally effective	Top of both levees necessary to contain 35,000 cfs.
33	43,000	D	Totally effective	Totally effective	Top of both levees necessary to contain 43,000 cfs.
34	35,000	D	Totally effective	Totally effective	Top of both levees necessary to contain 35,000 cfs.

* The "X3" option (assuming no effective flow landward of and below the top of levee elevation) was used for all cases that involve overtopping, with the exception of Case 0.

Case Number	Discharge in cfs	Levee Alignment	Minnesota Levee Condition*	North Dakota Levee Condition*	Notes
35	43,000	D	Totally effective	Existing-overtopped	Top of MN levees necessary to contain 43,000 cfs.
36	35,000	D	Totally effective	Existing-overtopped	Top of MN levees necessary to contain 35,000 cfs.
37	35,000	-	None	None	-
38	43,000	D	Totally effective	No levees but existing roadways left in place-overtopped	Top of MN levees necessary to contain 43,000 cfs.
39	35,000	D	Totally effective	No levees but existing roadways left in place-overtopped	Top of MN levees necessary to contain 35,000 cfs.
40	35,000	D	Totally effective	Existing-overtopped	Most probable water surface profile.
41	43,000	D	Totally effective	Existing-overtopped	Most probable water surface profile.

* The "X3" option (assuming no effective flow landward of and below the top of levee elevation) was used for all cases that involve levee overtopping, with the exception of Case 0.

Case 0:

The first modification plan evaluated would allow the levees to remain along their existing alignments but would lower the top elevations to conform with the criteria. Use of the X3 option which assumes no effective flow landward of and below the top elevation of the levees yields a top elevation that results in levees of negligible height. For this particular plan, then, flow landward of and below the top of the levees is significant and needs to be considered to give a more accurate estimate of allowable levee height. Further analysis of the interaction between channel and overbank flows indicates that substantial "crossover" flows take place between the channel and overbank areas once the levees overtop. To allow these flows to pass over levees with negligible head loss, levee height must be substantially lower than the maximum water surface, which in this case is the 1-percent chance flood plus one-half foot. For the condition where the entire floodplain can be utilized by flood flows overtopping the levees, the top of levee height should be set to an estimated elevation of 1.6 feet below the 1-percent chance flood profile. For levees that are well maintained and have mowed tops, this elevation could be adjusted to an estimated level of 1.3 feet below the 1-percent chance floc

Within the limitations of a one-dimensional model and the technical accuracy associated with discharge measurements, frequency curves, and high-water mark elevations, this type of analysis based on energy calculations is the most reasonable evaluation of levee overtopping that can be made.

Cases 1 to 4:

These four cases are based on the peak flow (43,000 cfs) observed at Oslo during the 1975 summer flood. Case 1 represents the profile for the without-levee condition, and the profiles for Cases 2, 3, and 4 represent the levee top elevations necessary to contain 43,000 cfs for Alignments A, B, and C, respectively.

Cases 5 to 7:

Using the X3 option, these cases represent the profiles for a 1-percent chance flood with the levees built to contain a flow of 43,000 cfs. Case 5 corresponds to Case 2 levees, Case 6 to Case 3 levees, and Case 7 to Case 4 levees. The results of the overtopping analysis used for Case 0 can be expected to apply here, giving a maximum water surface approximately 1.6 feet above the top of levee elevation.

Cases 8 to 10:

With the top of levee elevation set equal to the 1975 summer flood high-water profiles, the maximum water surface was set to the same level as the criteria (i.e., one-half foot above the level of the 1-percent chance flood) to determine the flow capacity at that level. For Alignments A, B, and C, the flows yielding a water surface one-half foot above the 1-percent chance flood profile are 39,000, 32,500, and 34,500 cfs, respectively. Note that the levees are overtopped in these cases, and the X3 option is utilized.

Cases 11 to 13:

These cases represent the profiles calculated for a 1-percent chance flood overtopping levees built to a height equal to the high-water profile of the 1975 summer flood. As before, Alignments A, B, and C are used as is the X3 option.

Cases 14 to 16:

Again, the effect of a 1-percent chance flood flow is evaluated, but for these cases the top of levee elevations are set equal to the level of the 1975 summer flood plus 1 1/2 feet.

Case 17:

The purpose of evaluating this case was to determine the levee height necessary to achieve 43,000-cfs protection on the Minnesota side, along the existing alignment (alignment A), with the North Dakota agricultural levees remaining unchanged from existing conditions.

Case 18:

This case represents an attempt to determine whether the Minnesota levees could be adjusted along the existing alignment to meet the States' criteria with North Dakota levees left as is. The presence of existing North Dakota levees alone, with no agricultural levees at all on the Minnesota side, raises the stage of the 1-percent chance flood 2.3 feet at Oslo.

Cases 19 to 21:

These three cases represent the water surface that could be expected with a flow of 43,000 cfs if the levees were built to match the 1975 high-water profile. At first glance, it would seem that levees built to the profile of the 1975 summer flood should contain the flow of the 1975 summer flood, but the presence of the agricultural levees raises the stage significantly for that flow and the levees would be overtopped.

Cases 22-23:

Cases 22 and 23 are multiple profiles for discharges from 30,000 cfs to 40,000 cfs, in 2,000-cfs intervals for Alignments B and C, respectively.

Cases 24 to 26:

As in cases 8 to 10, 11 to 13, and 19 to 21, the top of levee elevation is equal to the high-water profile of the 1975 summer flood. The discharges shown in the table (27,000 cfs for Case 24, 26,000 cfs for Case 25, and 26,500 cfs for Case 24) represent the maximum flow capacity of such levee systems built along Alignments A, B, and C, respectively.

Case 27:

For Alignment A, with levees on both sides of the river built to the level of the 1975 summer flood high water plus 1 foot, the maximum capacity is 30,500 cfs before the levees overtop.

Case 28:

This case includes profiles for flows from 30,000 cfs to 50,000 cfs, in 2,000-cfs increments, for Alignment A levees on both sides of the river. These profiles can be compared with Cases 22 and 23, which represent Alignments B and C, respectively.

Case 29:

This profile represents the top elevation of a Minnesota levee that would provide 43,000-cfs protection, with no agricultural levees at all on the North Dakota side.

Cases 30 to 32:

These three cases represent the top elevations of Minnesota levees to contain a flow of 35,000 cfs, with several different levee conditions on the North Dakota side. For Case 30, existing North Dakota levees remain in place and are overtopped by the 35,000-cfs flow. No North Dakota levees are assumed in place for Case 31, and, for Case 32, North Dakota levees would be built to a height equal to the Minnesota levees (i.e., to contain a 35,000-cfs flow).

Cases 33 and 34

Cases 33 and 34 use Alignment D, which specifies the existing alignment on the North Dakota side and a modified alignment (Alignment C) for the Minnesota levees. Case 33 is the top elevation profile for levees on both sides of the river that would contain a flow of 43,000 cfs; Case 34 is the levee profile for 35,000-cfs protection.

Cases 35 and 36

These two cases differ from Cases 33 and 34 in that the North Dakota agricultural levees are left as is, with no raising or extending of levees on that side of the river. As before, Alignment D is used for flows of 43,000 cfs and 35,000 cfs. The only difference between Cases 30 and 36 is the alignment of the levees on the Minnesota side.

Case 37:

Case 37 is a profile for a 35,000-cfs flow with no agricultural levees on either side of the river. This profile is useful for comparison with the other 35,000-cfs profile to determine the stage increase caused by the levee plans.

Cases 38 and 39:

One criticism of prior runs that involve overtopping of the existing North Dakota levees is that use of the X3 option yields a profile that is higher than would realistically occur. In cases where the top elevation of the Minnesota levees would be determined on the basis of this overtopping analysis of existing North Dakota levees (e.g., Cases 17, 30, 35, and 39), the resulting profile could be higher than necessary. In other words, use of the X3 option to determine an appropriate levee top elevation for 43,000-cfs protection on the Minnesota side will give a profile slightly too high, resulting in a greater degree of protection on the Minnesota side and greater adverse impacts on the North Dakota side. The North Dakota representatives therefore requested that we use a more realistic analysis of overtopping of existing North Dakota levees. One method of achieving a profile intermediate between a "without levee" condition and an "X3" condition for all existing levees is to remove all North Dakota levees in the model but leave the roadways that function as levees in place (using X3 when these roads overtop). At various locations along the river, particularly on the North Dakota side, the agricultural levees connect with sections of raised township roads. These roads act as levees, and are recognized as such by the HEC-2 model wherever a cross section intersects one of these raised roads. All other roads were left "as is"; that is, they were included in the model calibration parameters. Cases 38 and 29 represent this assumption for flows of 43,000 cfs and 35,000 cfs, respectively.

Cases 40 and 41:

The working group decided that the most accurate profiles for 35,000- and 43,000-cfs protection levees on the Minnesota side, with existing North Dakota levees left as is, would be derived by use of engineering judgment based on previous model runs. Therefore, a meeting was held with engineers from the

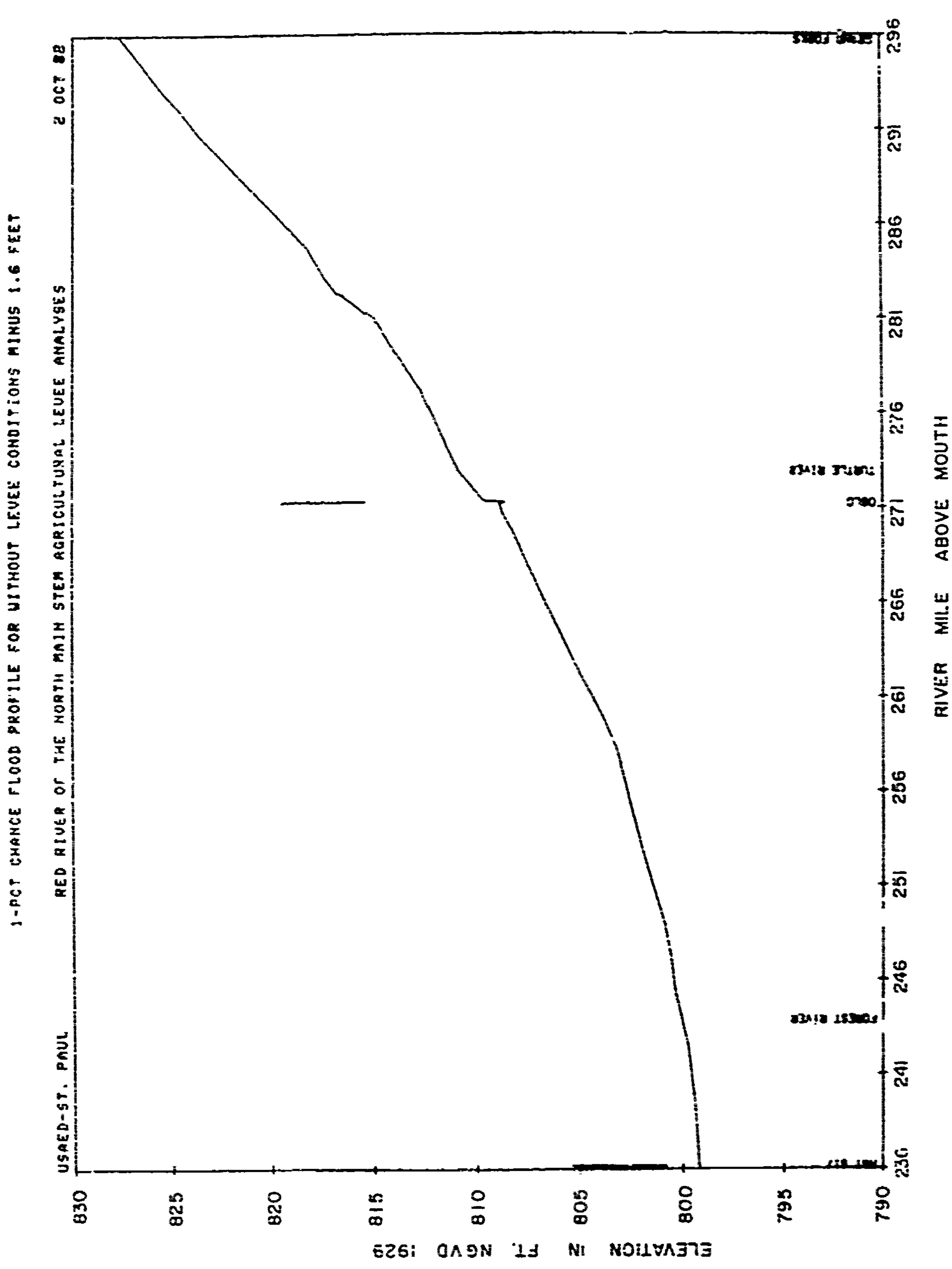
Minnesota Department of Natural Resources, North Dakota State Water Commission, Middle River-Snake River Watershed District, and Corps to determine the most probable water surface profiles for these specific conditions. The rationale for doing these profiles is based on the following:

a. Use of the 1975, 1978, and 1979 flood profiles as a guide.

b. Evaluation of model-generated profiles for 35,000 cfs and 43,000 cfs and comparison of these with the historic profiles.

c. Weighting of the historic profile somewhat more than the computed profiles and determination of "best fit" profiles on the basis of discussion and engineering judgment.

The result is shown as Cases 40 and 41, which represent the top elevations for Minnesota levees providing 35,000- and 43,000-cfs protection, respectively, with no raise or extension of existing North Dakota agricultural levees.


1-PCT CHANCE FLOOD PROFILE FOR WITHOUT LEVEE CONDITIONS MINUS 1.6 FEET
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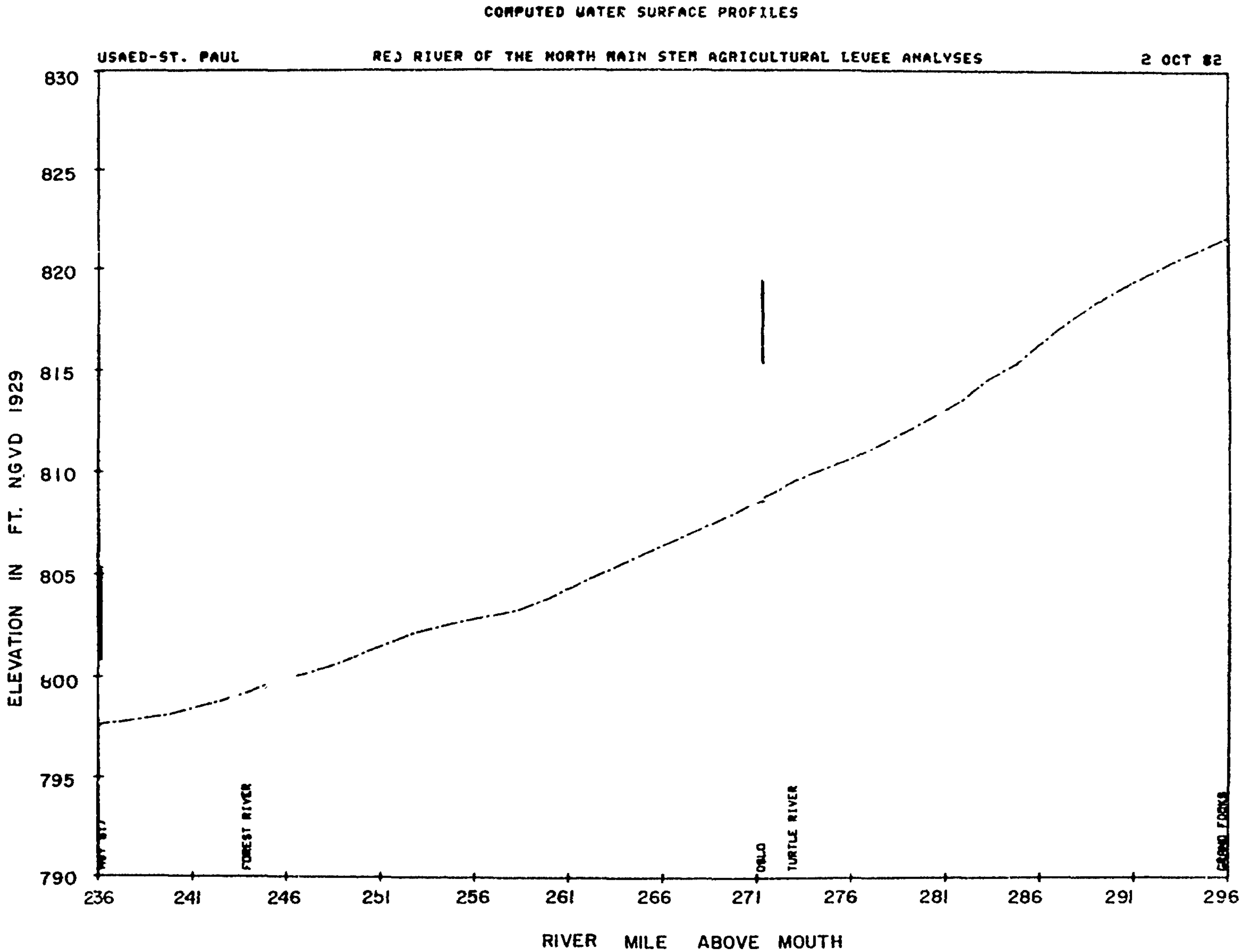
CASE 0


COMPUTED WATER SURFACE PROFILES
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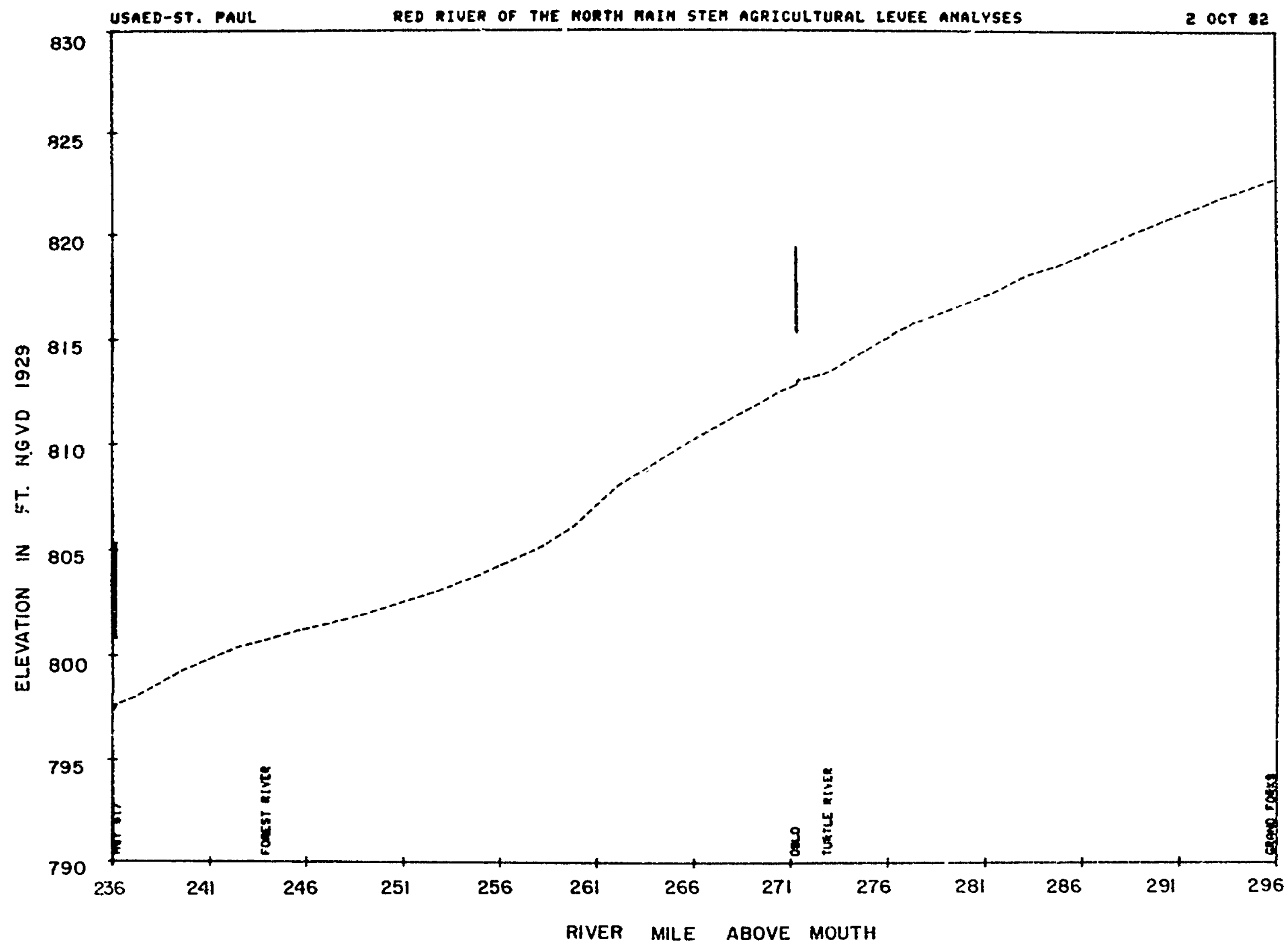
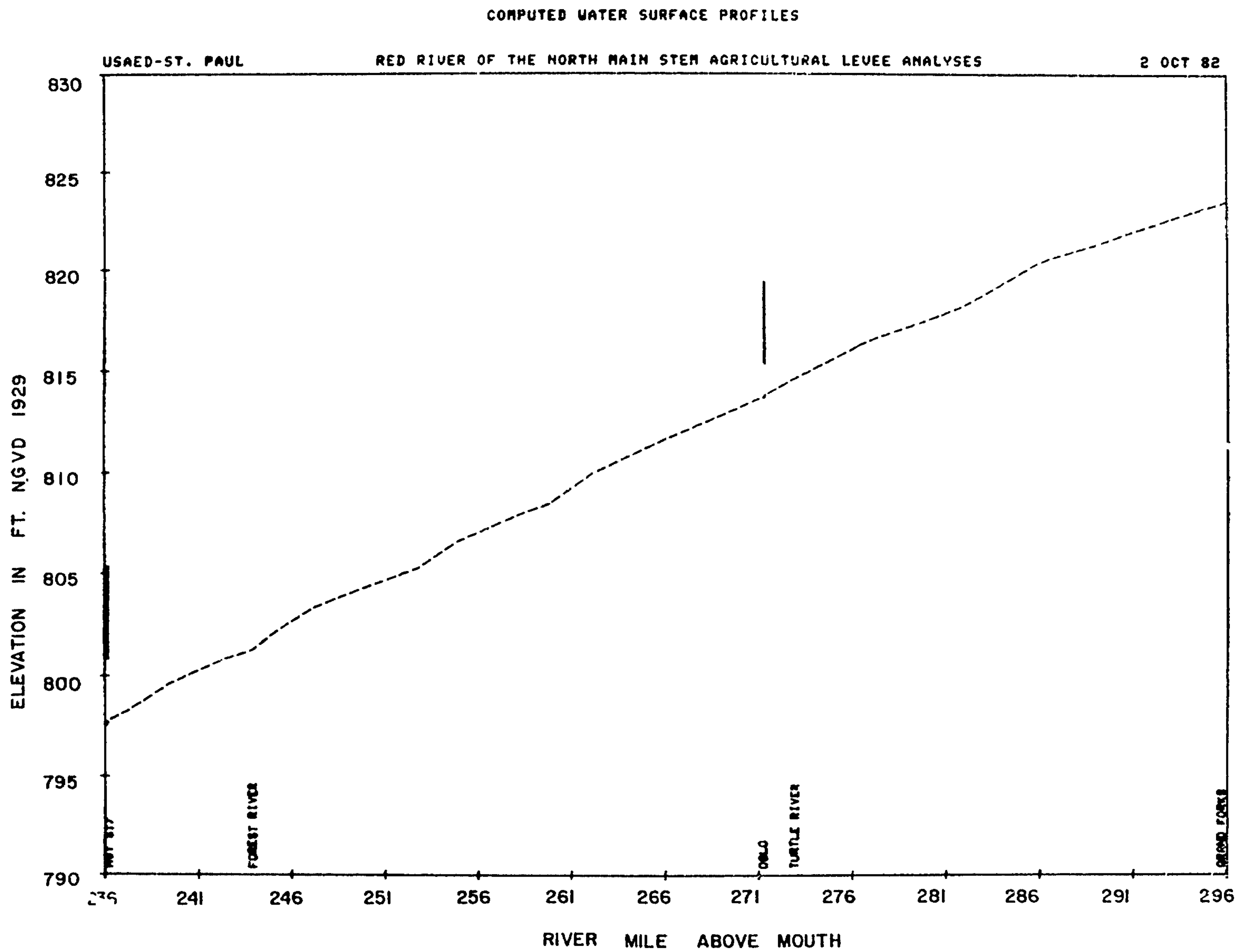
CASE 1

COMPUTED WATER SURFACE PROFILES



CASE 2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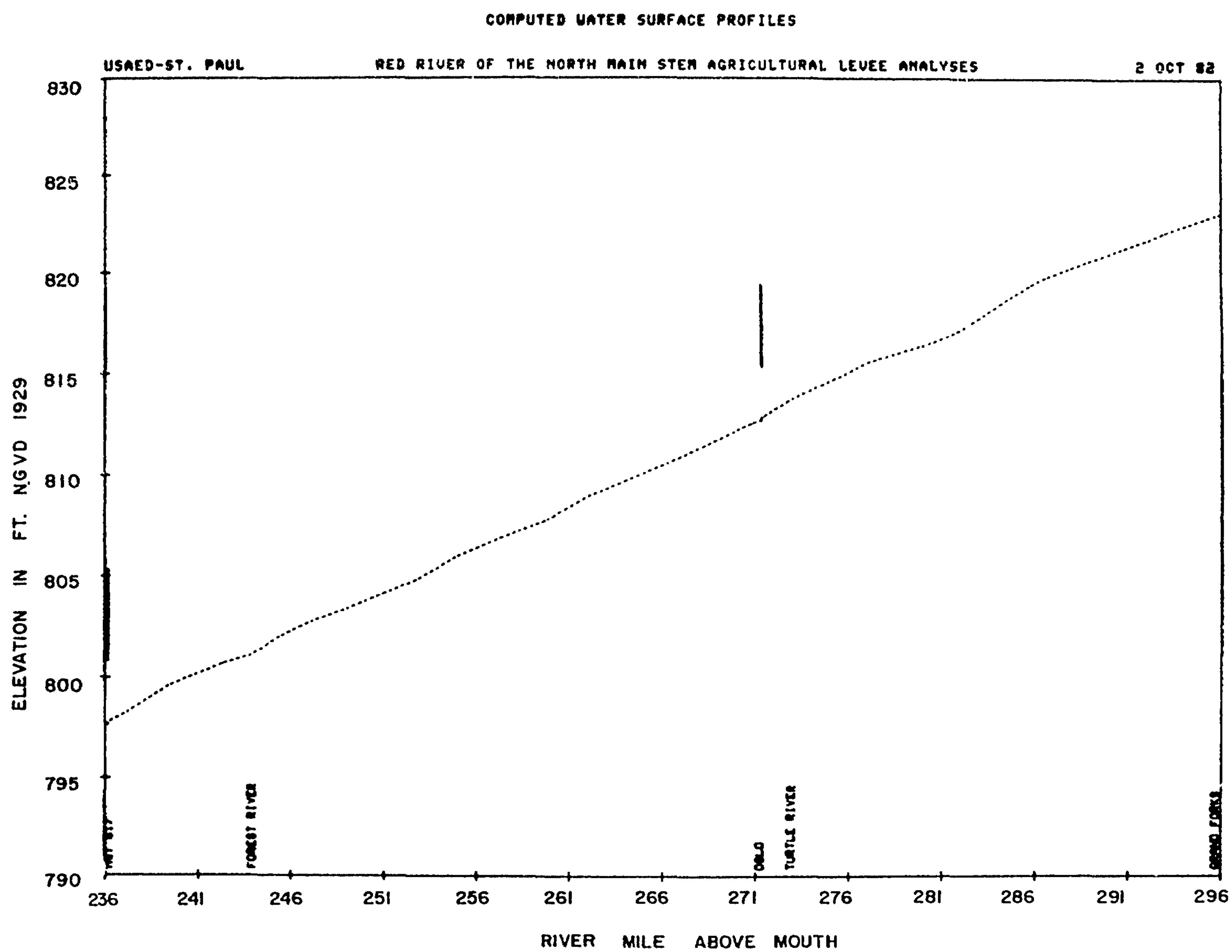
CASE 3


COMPUTED WATER SURFACE PROFILES
USAED-ST. PAUL
RED RIVER OF THE NORTH MAIN STEM AGRICULTURAL LEVEE ANALYSES
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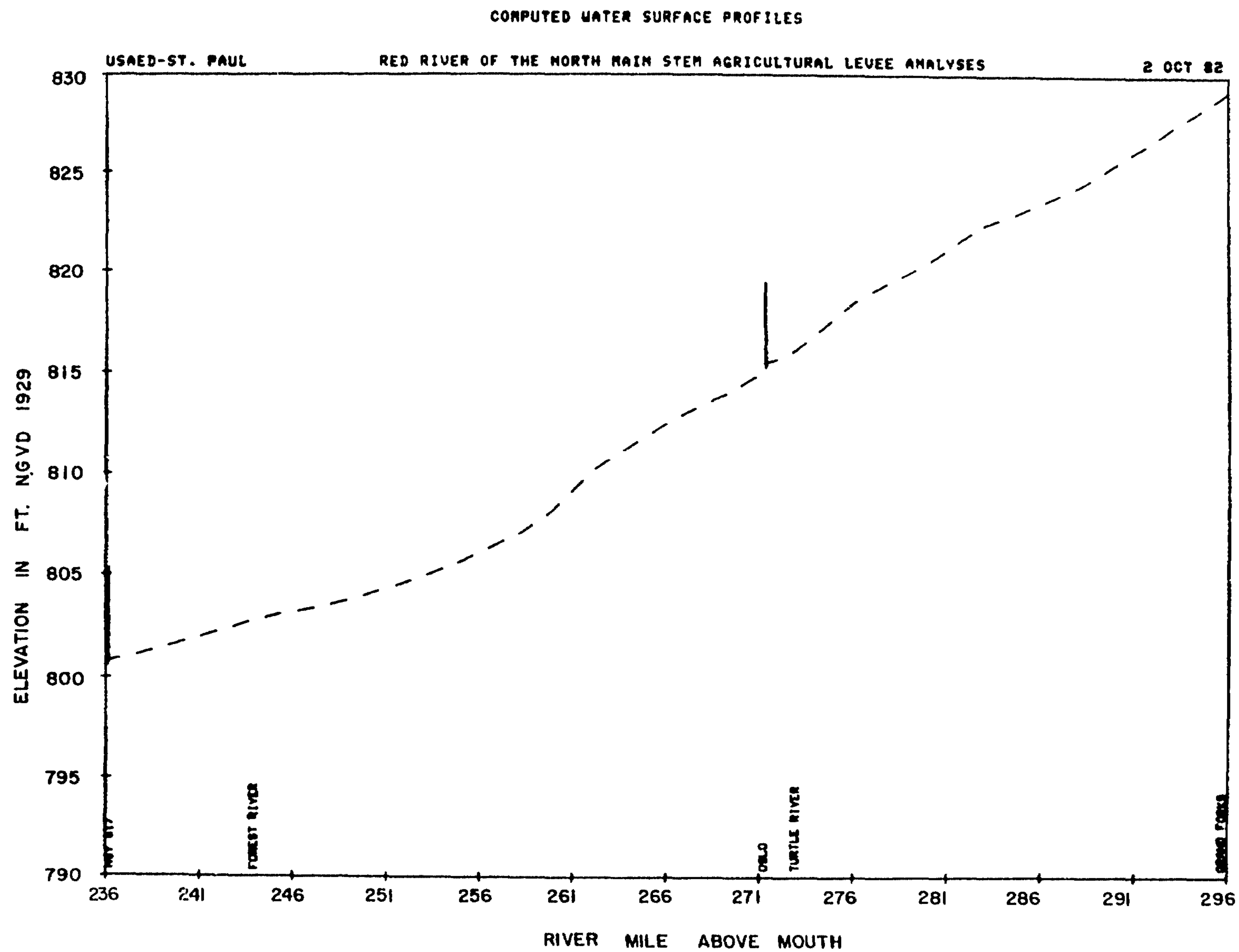
CASE 4



COMPUTED WATER SURFACE PROFILES
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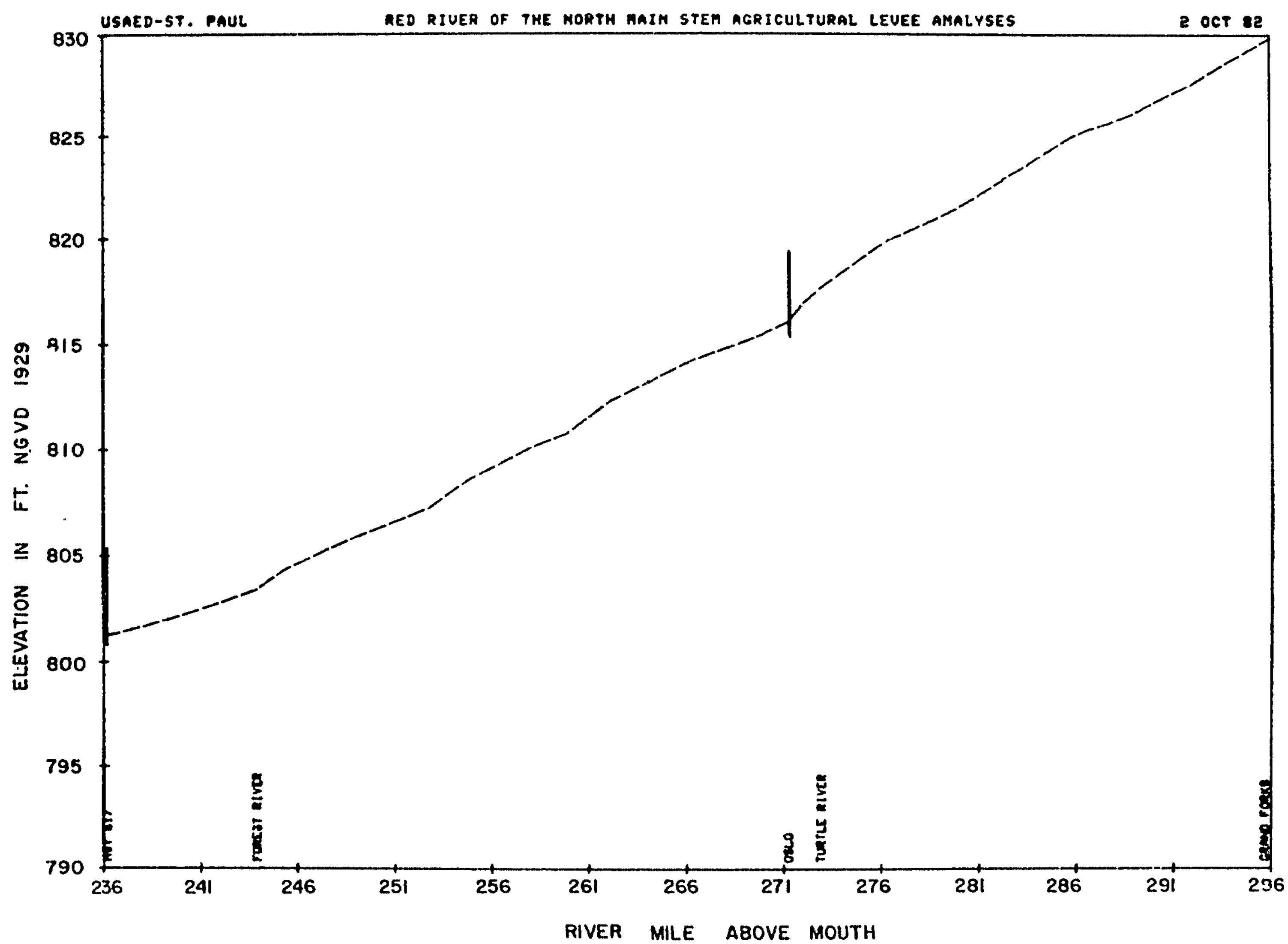
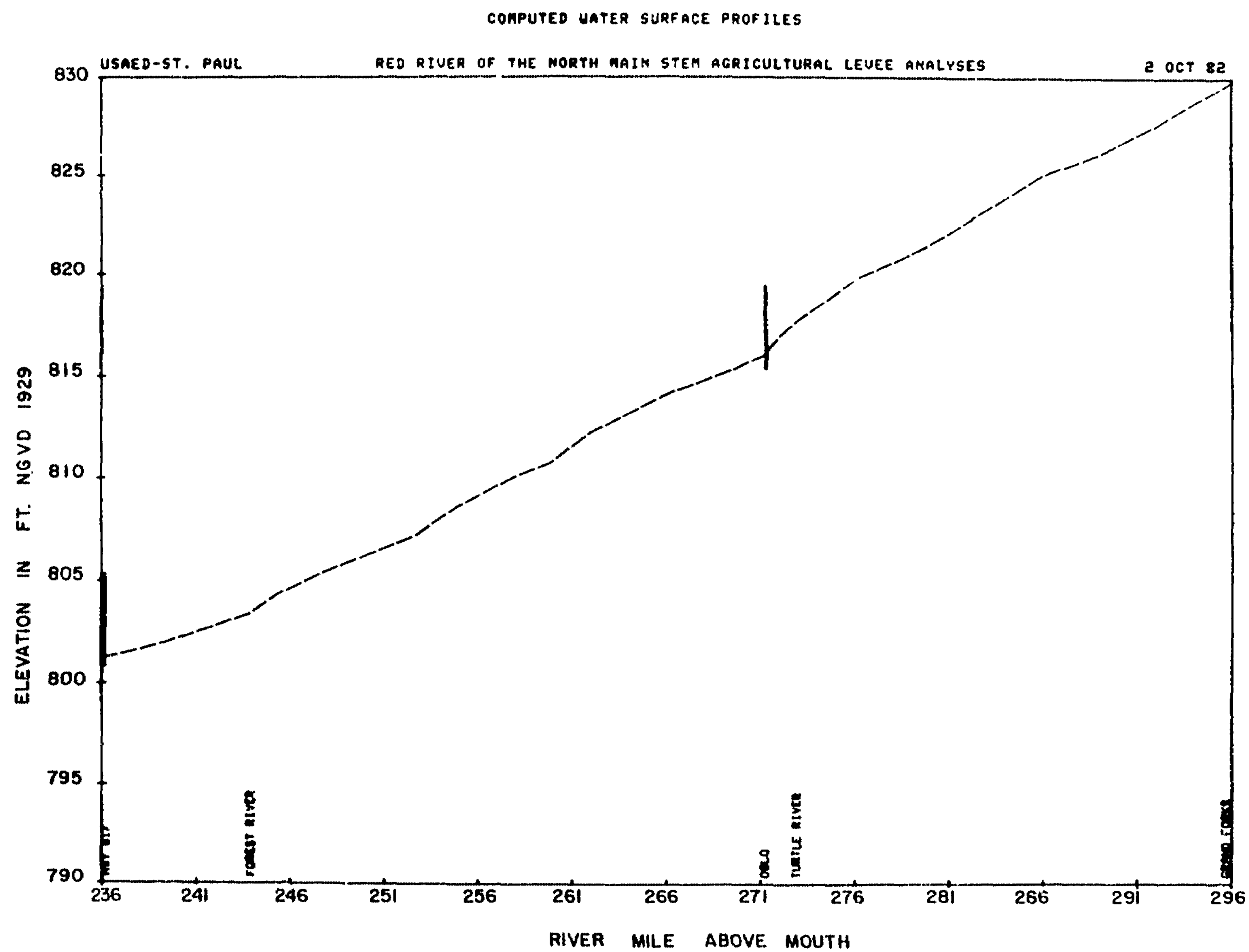
CASE 5

COMPUTED WATER SURFACE PROFILES



CASE 6


COMPUTED WATER SURFACE PROFILES
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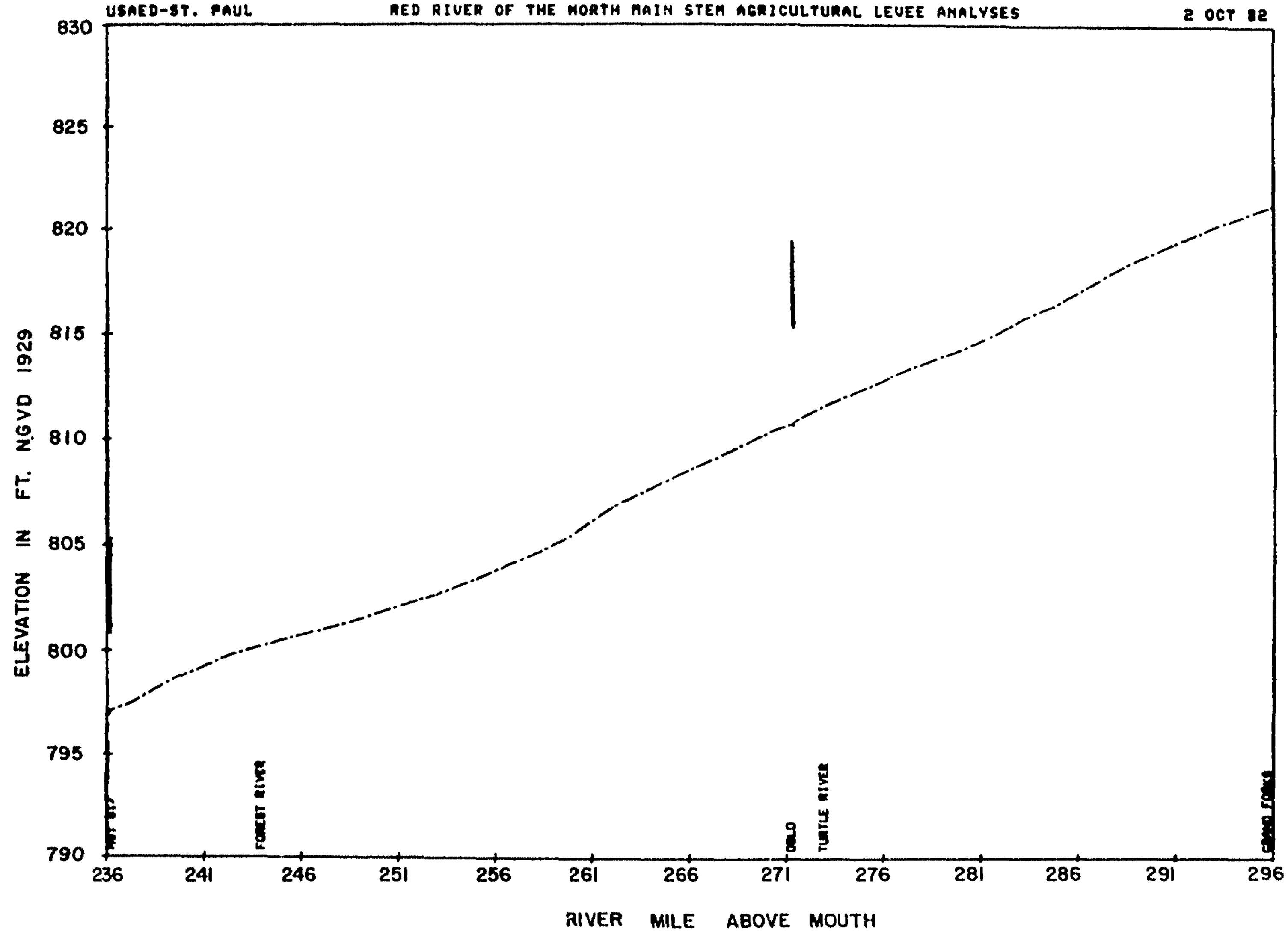
RIVER MILE ABOVE MOUTH

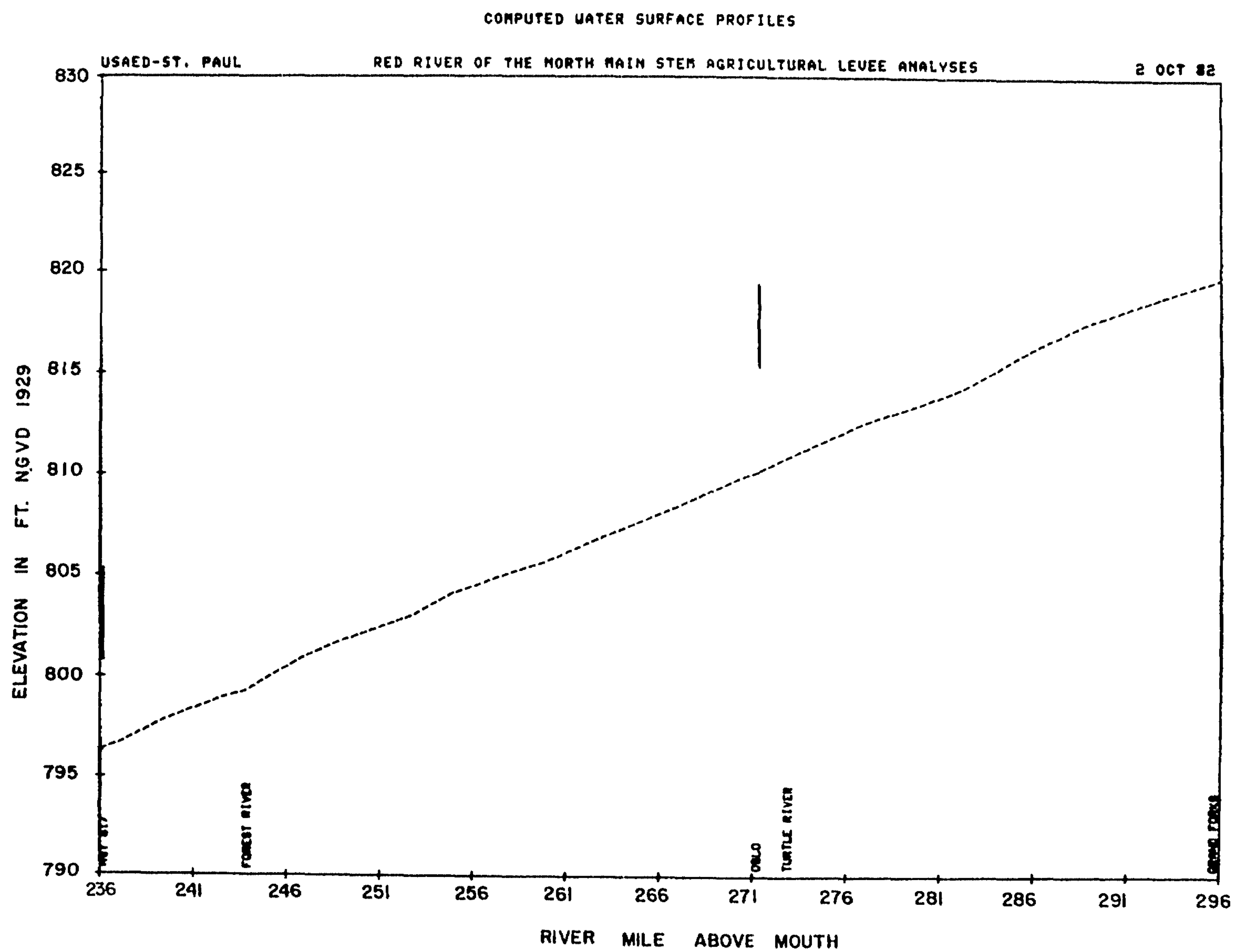
CASE 7

COMPUTED WATER SURFACE PROFILES

USAED-ST. PAUL — RED RIVER OF THE NORTH MAIN STEM AGRICULTURAL LEVEE ANALYSES — 2 OCT 82



CASE 8


COMPUTED WATER SURFACE PROFILES
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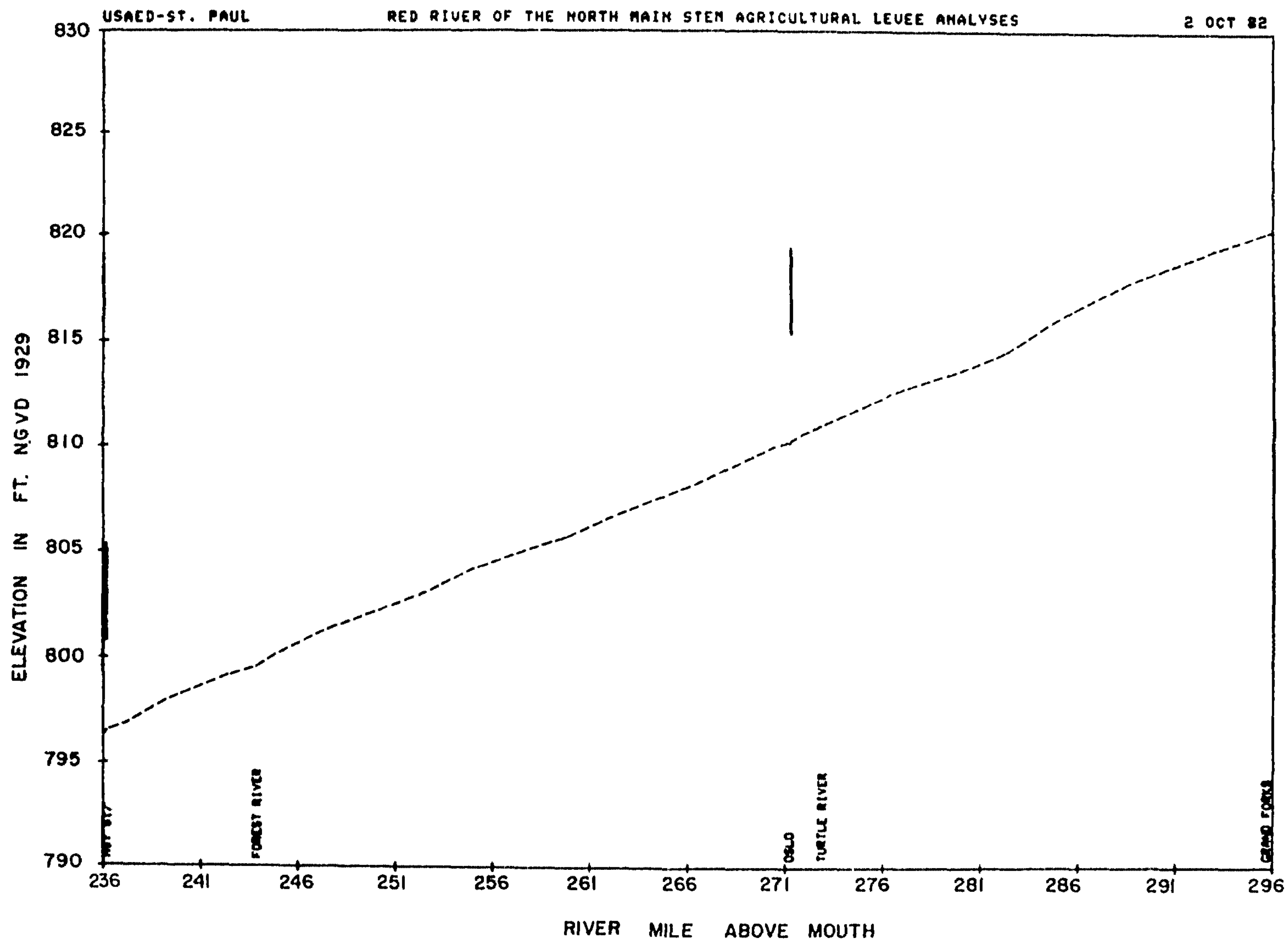
CASE 9

COMPUTED WATER SURFACE PROFILES



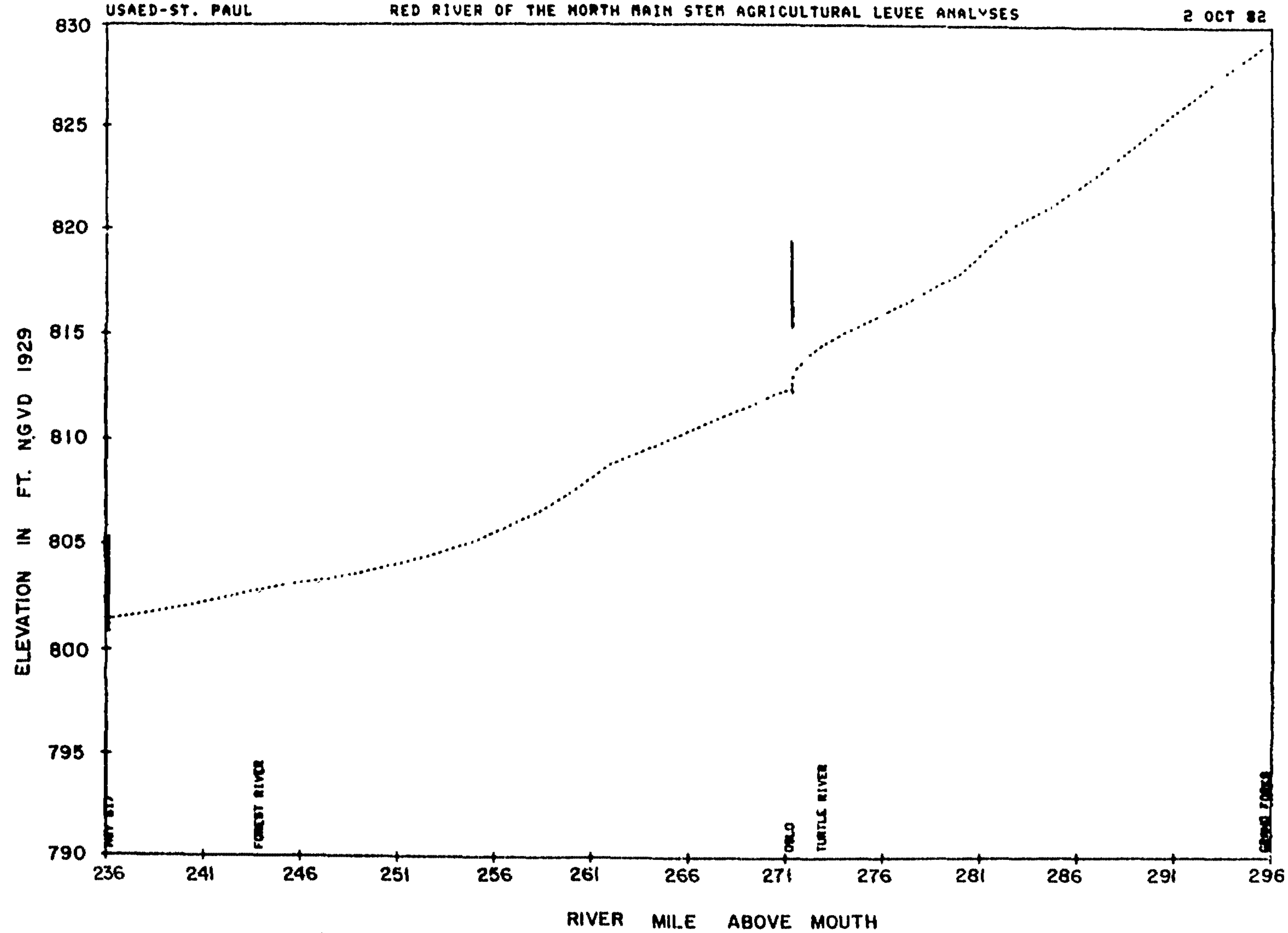
CASE 10

COMPUTED WATER SURFACE PROFILES

USAED-ST. PAUL

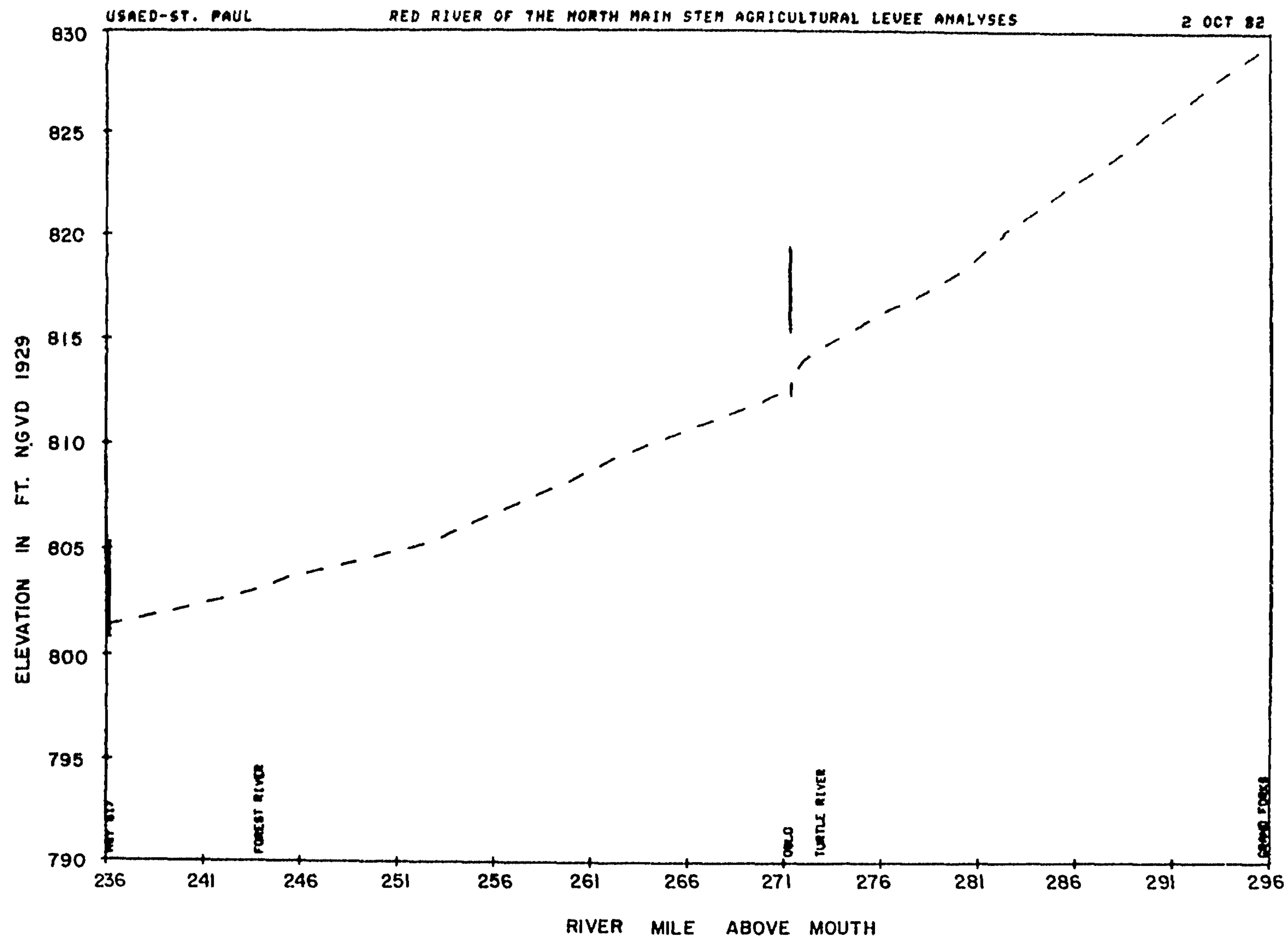
RED RIVER OF THE NORTH MAIN STEM AGRICULTURAL LEVEE ANALYSES

2 OCT 82



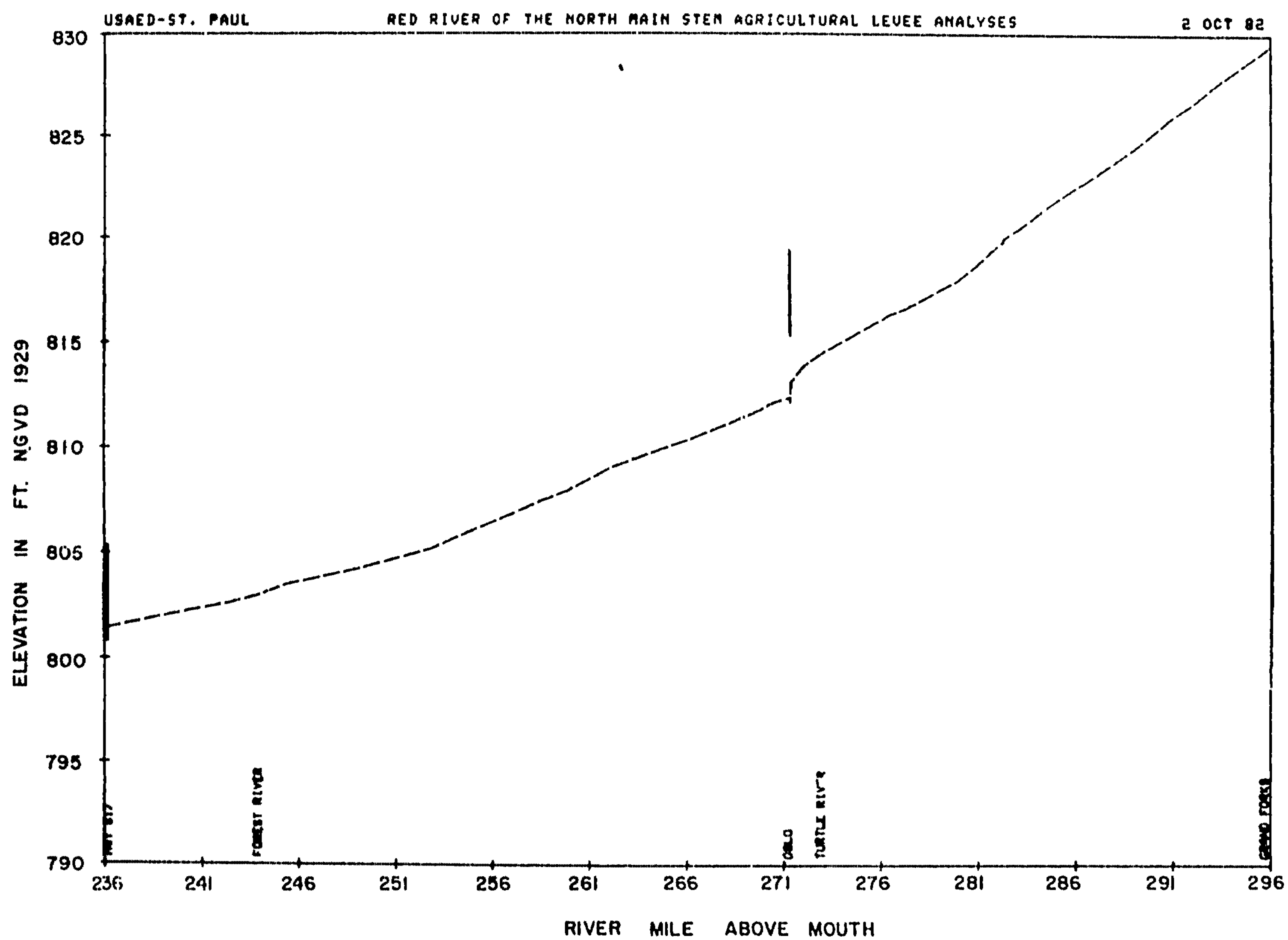
CASE 11

COMPUTED WATER SURFACE PROFILES

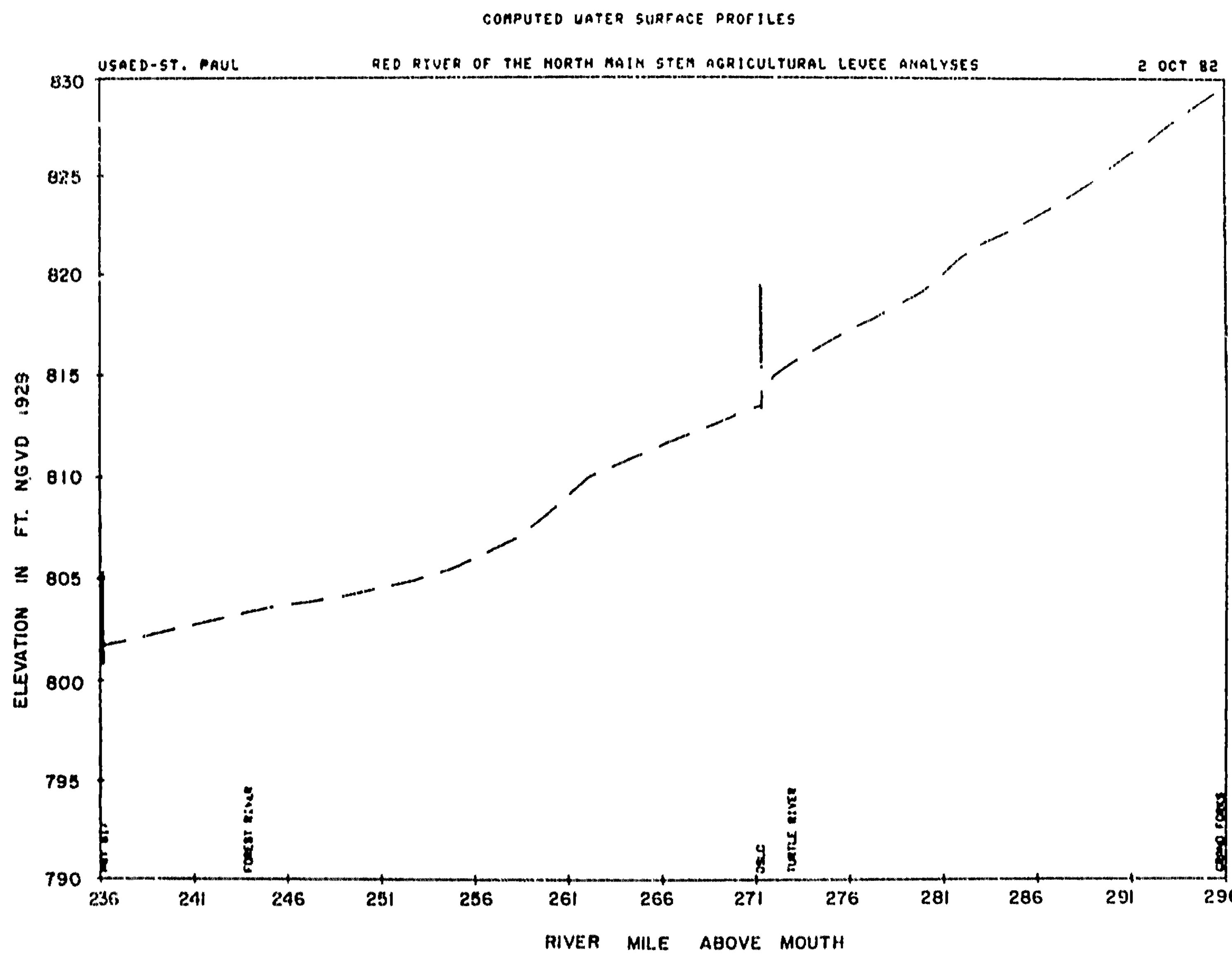


CASE 12

COMPUTED WATER SURFACE PROFILES



CASE 13


COMPUTED WATER SURFACE PROFILES
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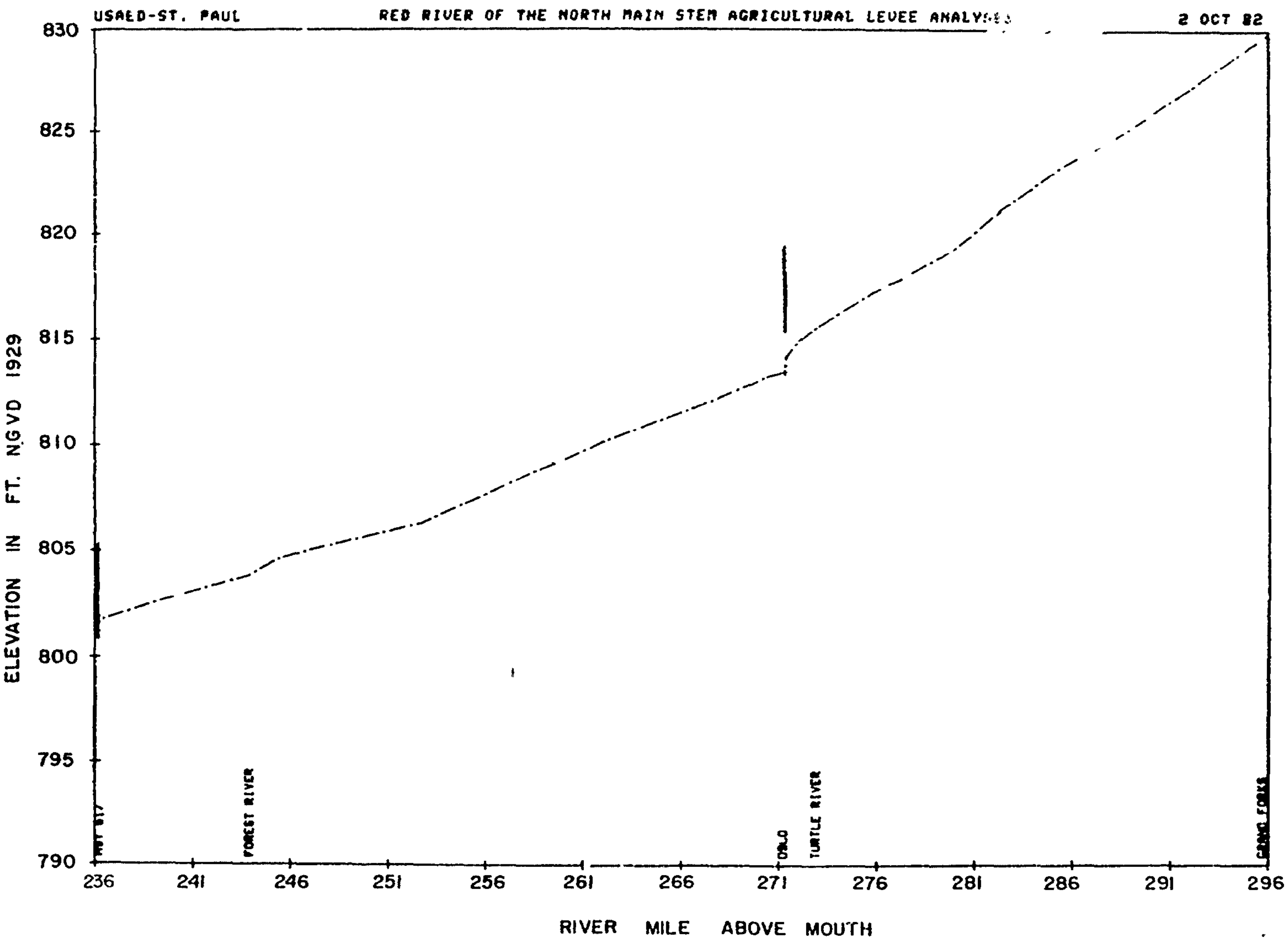
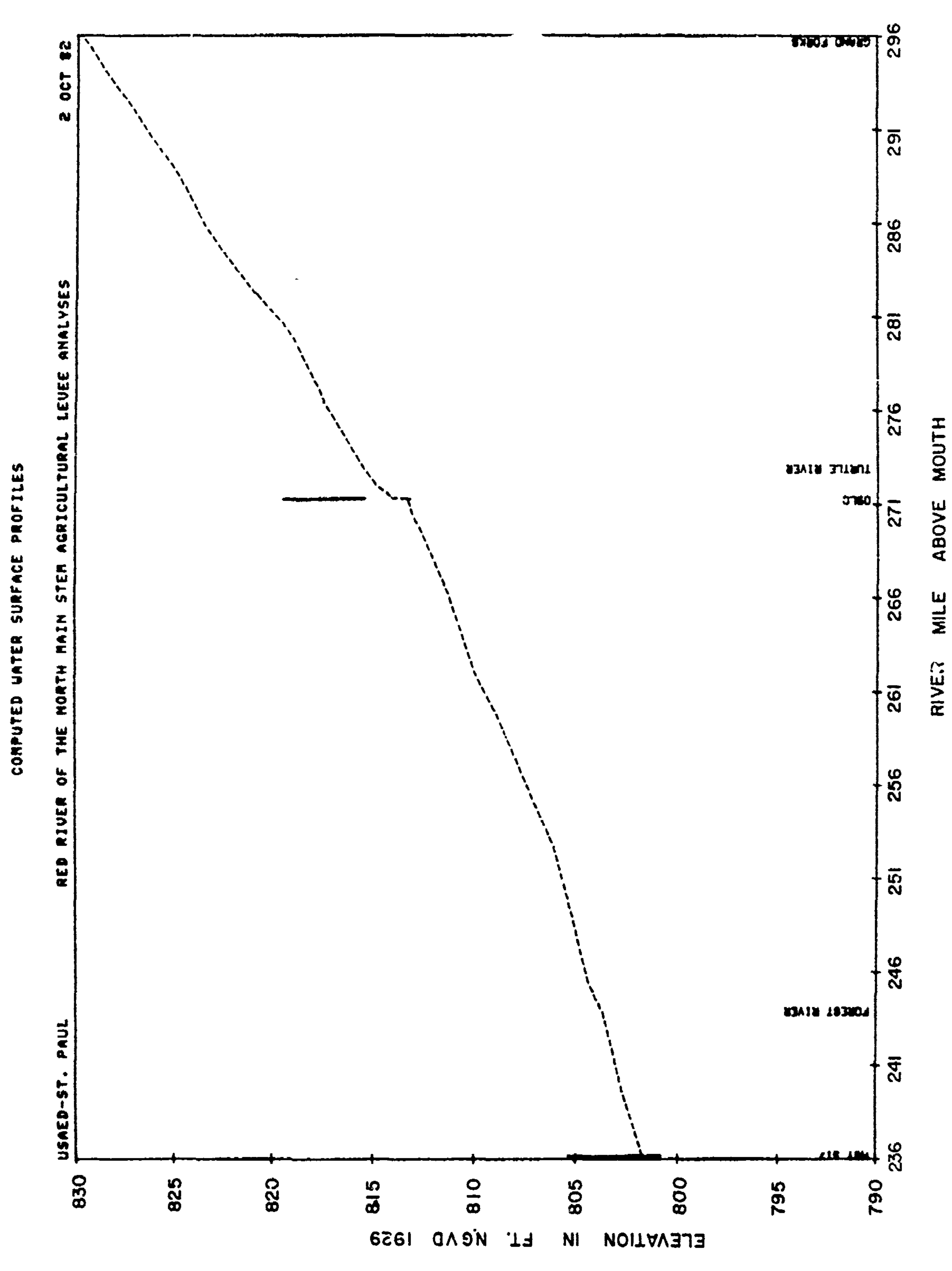
CASE 14

COMPUTED WATER SURFACE PROFILES



CASE 15


COMPUTED WATER SURFACE PROFILES
RED RIVER OF THE NORTH MAIN STEM AGRICULTURAL LEVEE ANALYSES
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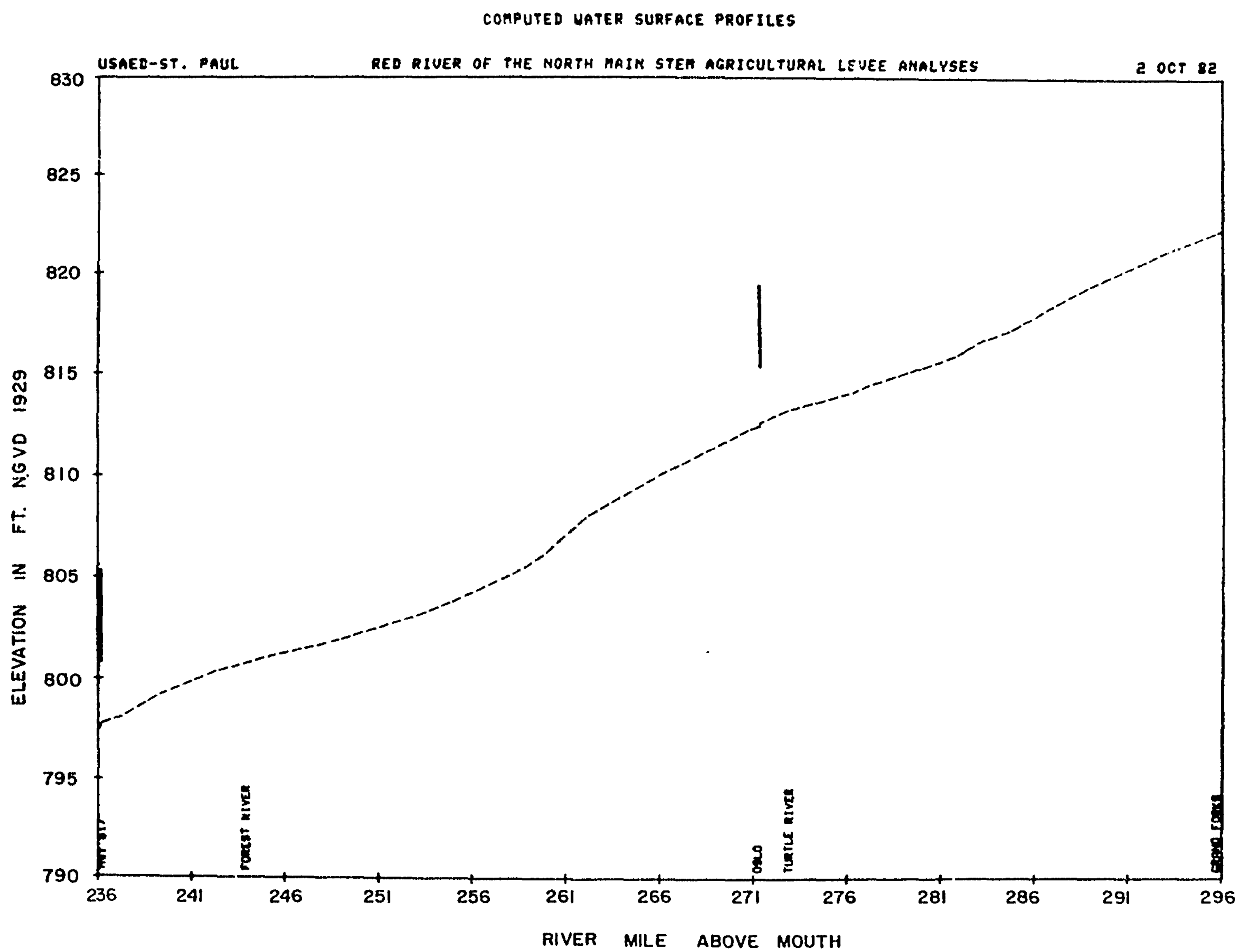
CASE 16


COMPUTED WATER SURFACE PROFILES
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RIVER MILE ABOVE MOUTH

CASE 17

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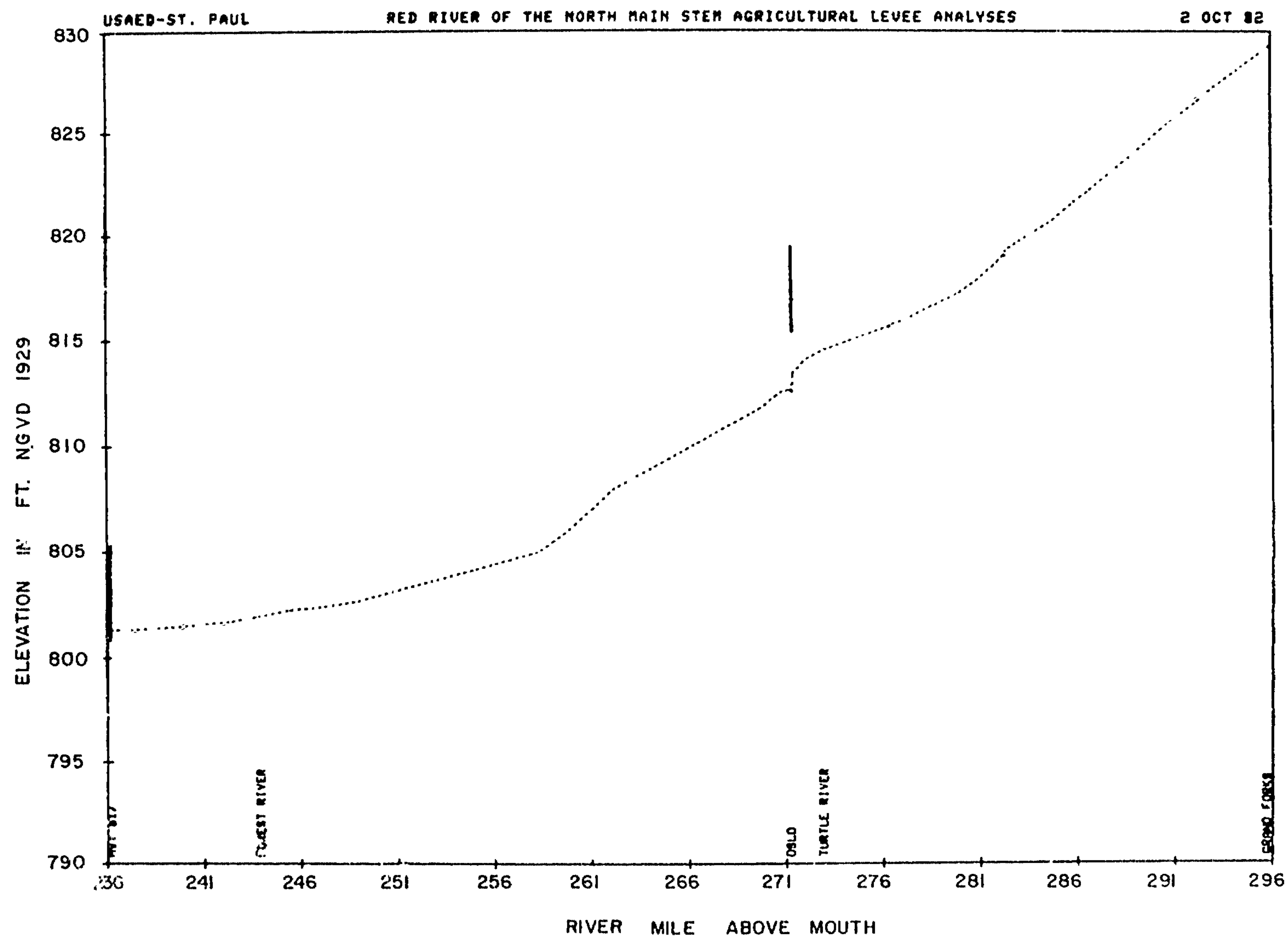

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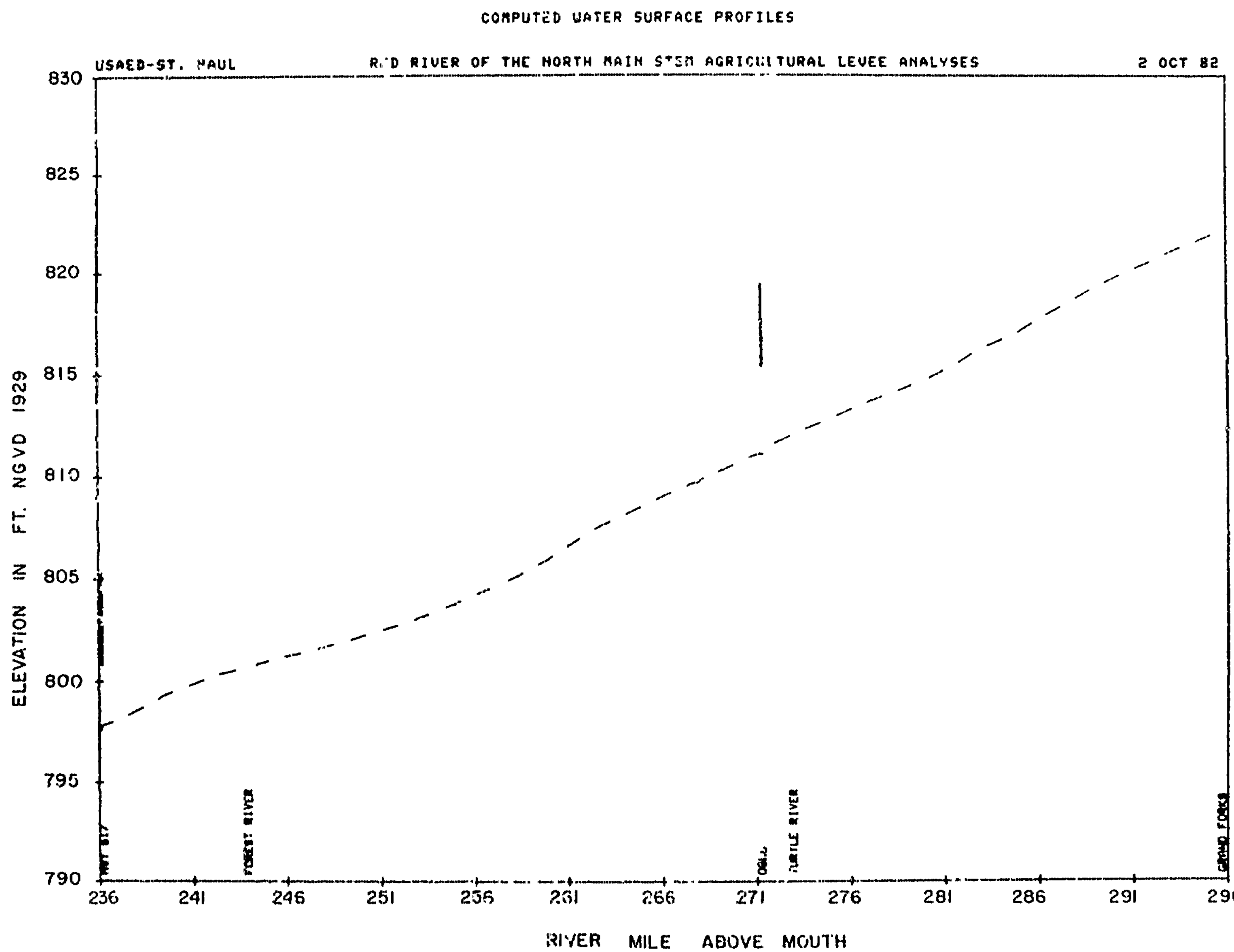
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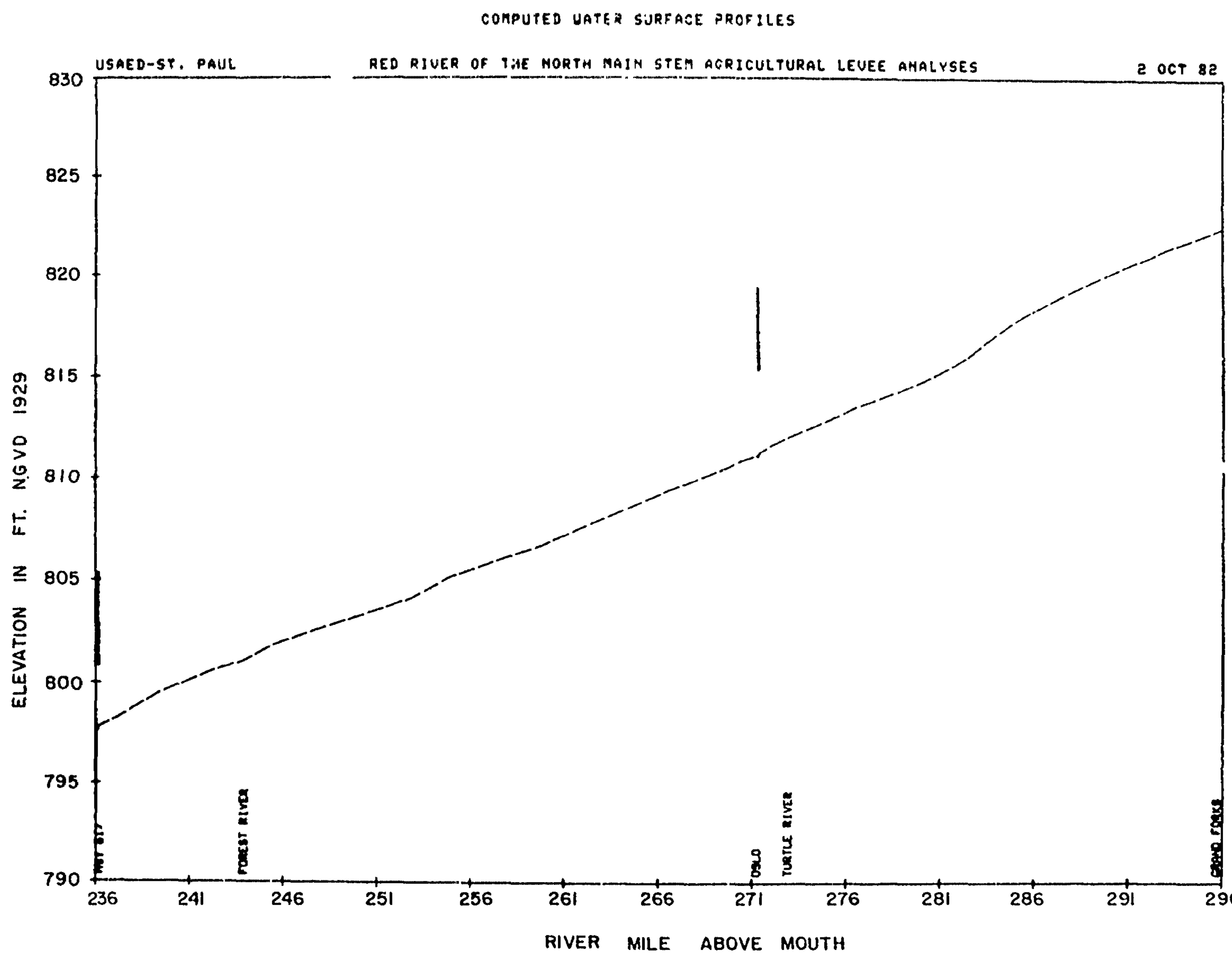
RIVER MILE ABOVE MOUTH

CASE 19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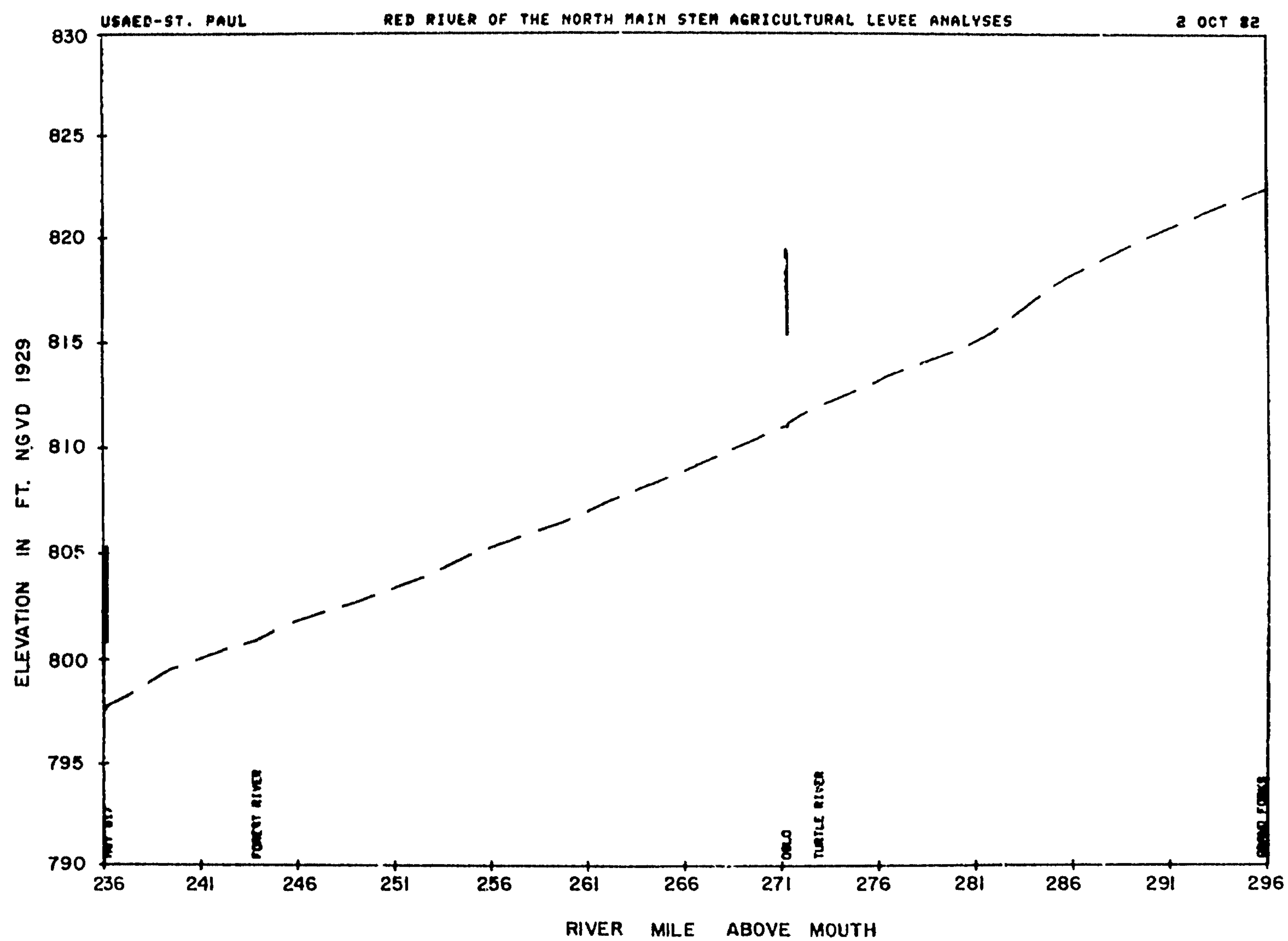
RIVER MILE ABOVE MOUTH

CASE 20

COMPUTED WATER SURFACE PROFILES



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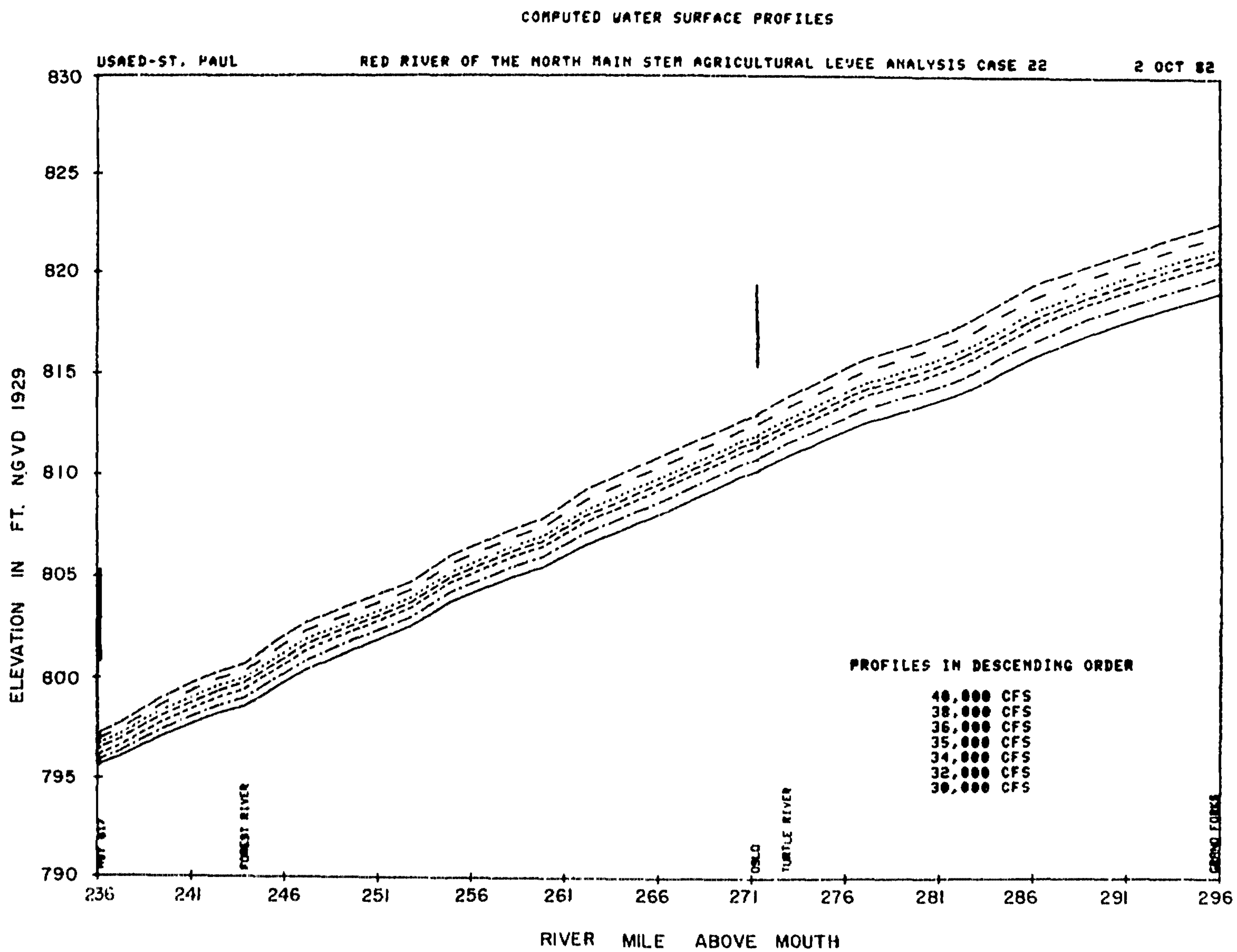
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RIVER MILE ABOVE MOUTH
FOREST RIVER
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GRAND FORKS
PROFILES IN DESCENDING ORDER
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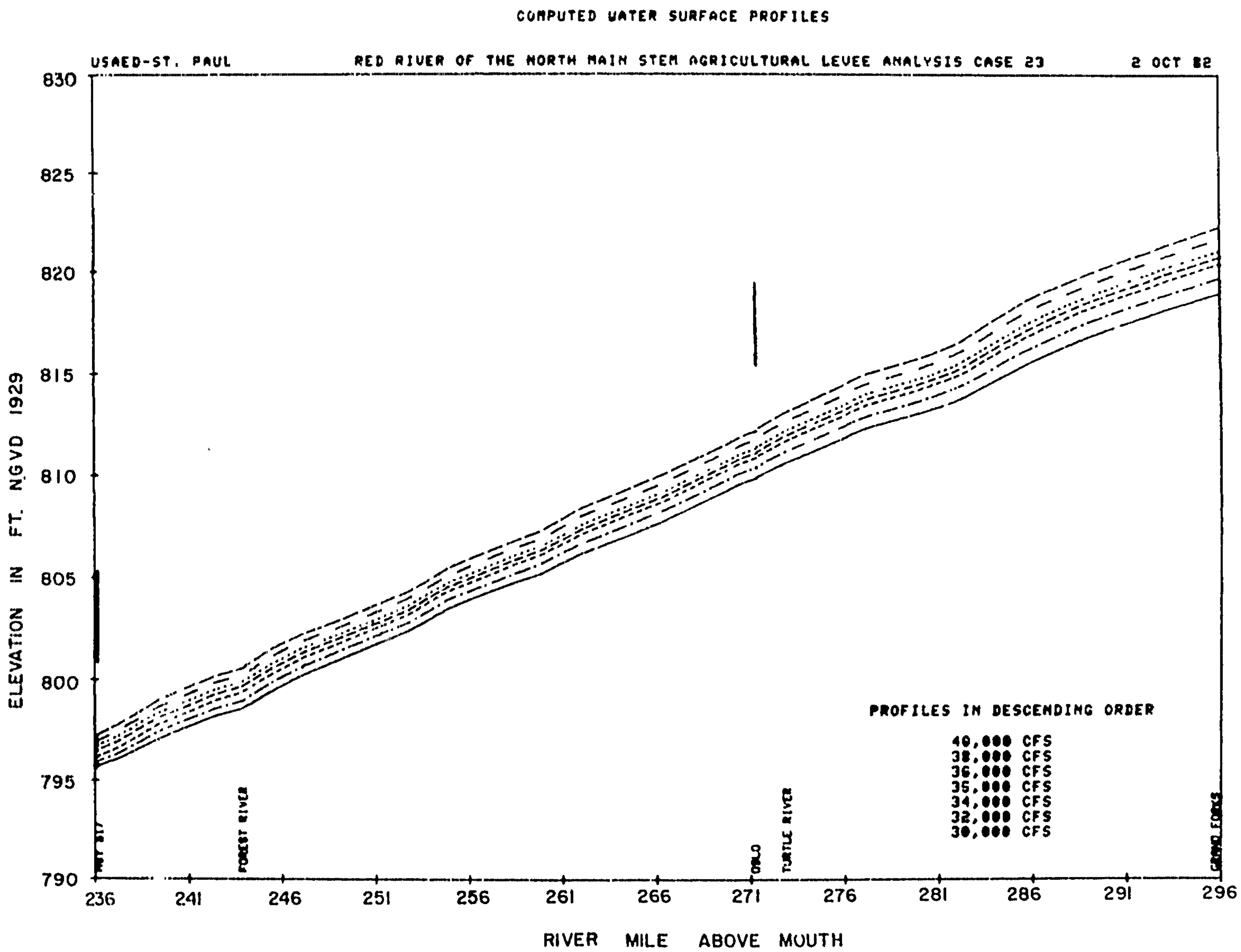
CASE 22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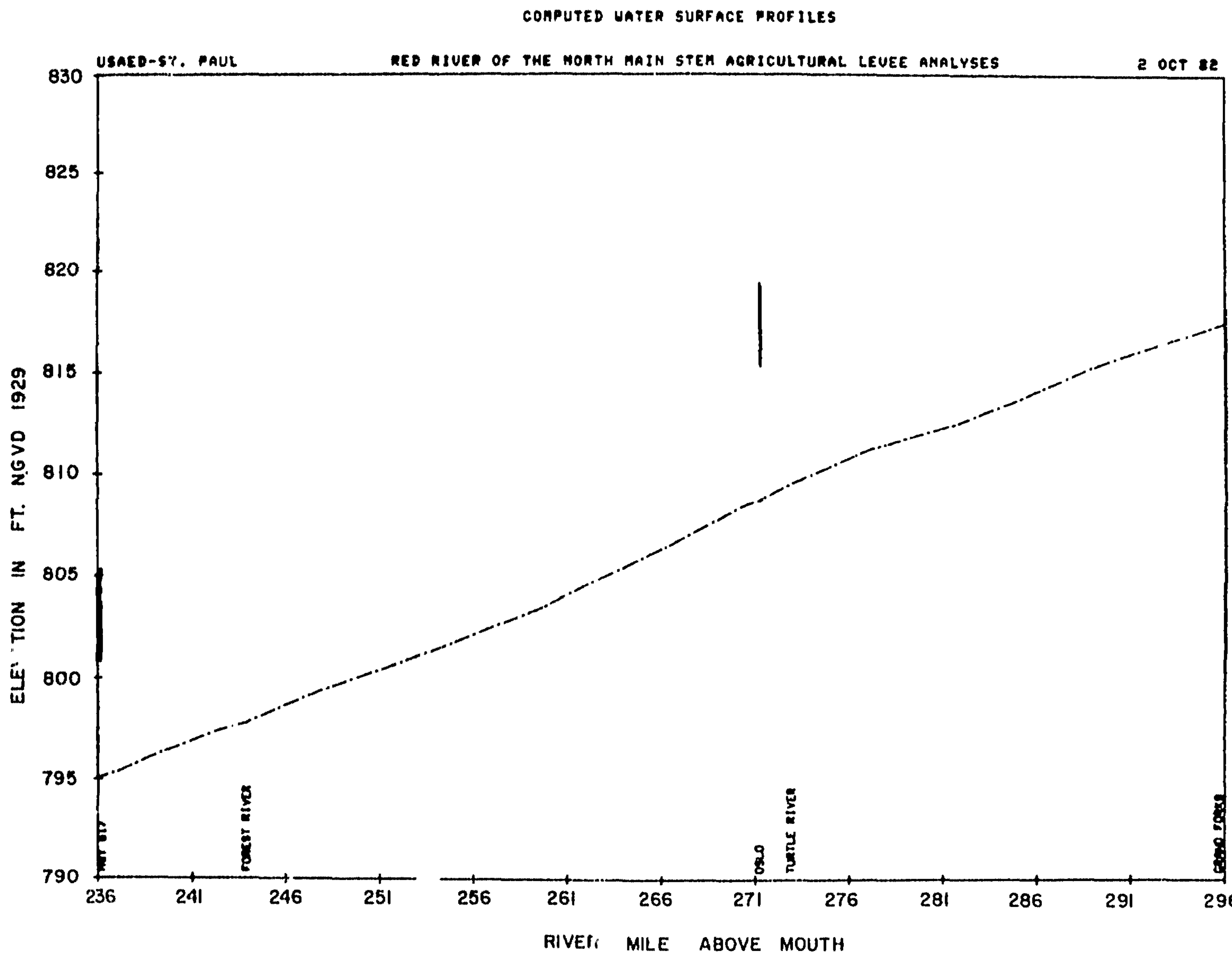
RIVER MILE ABOVE MOUTH

CASE 23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FOREST RIVER
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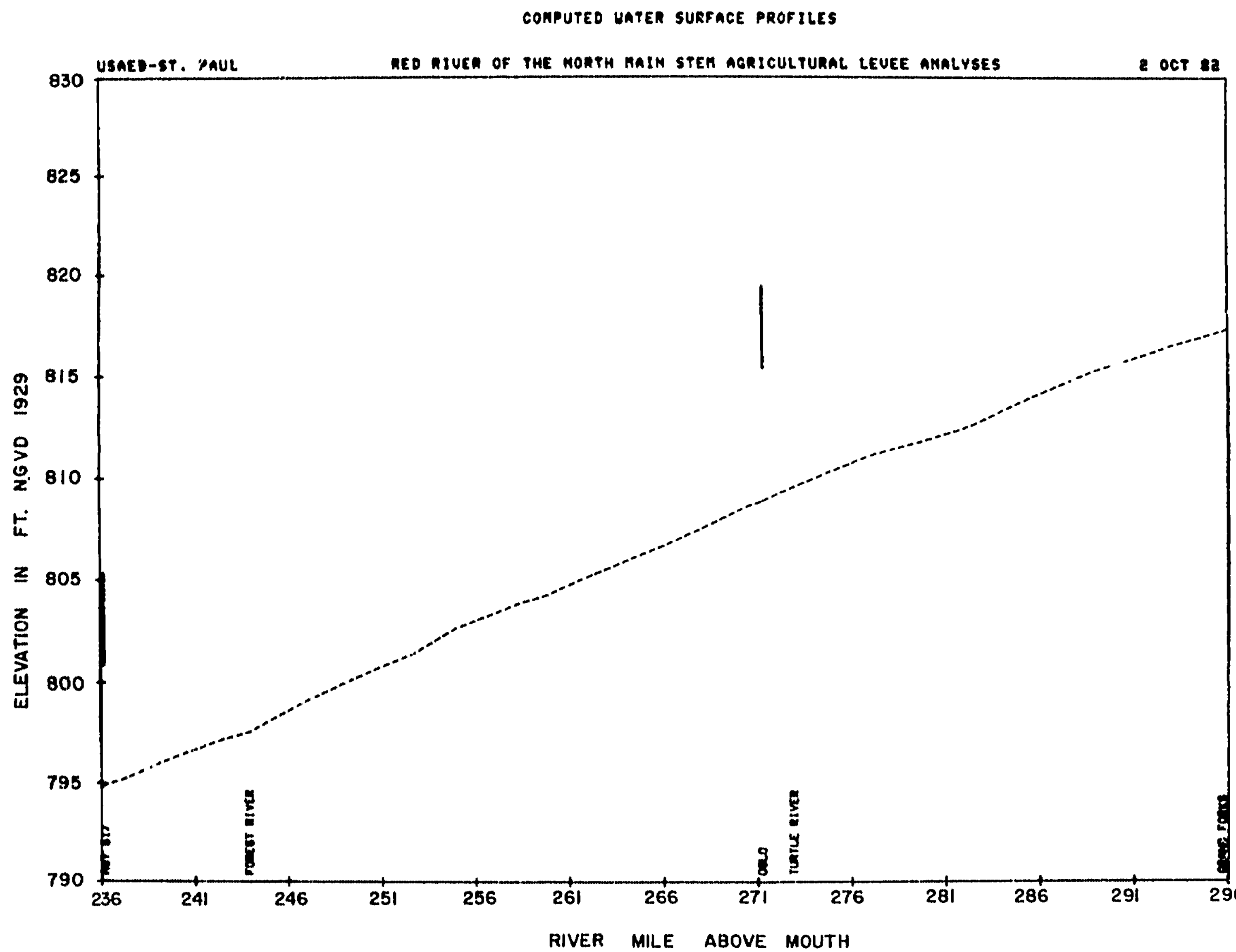
CASE 24



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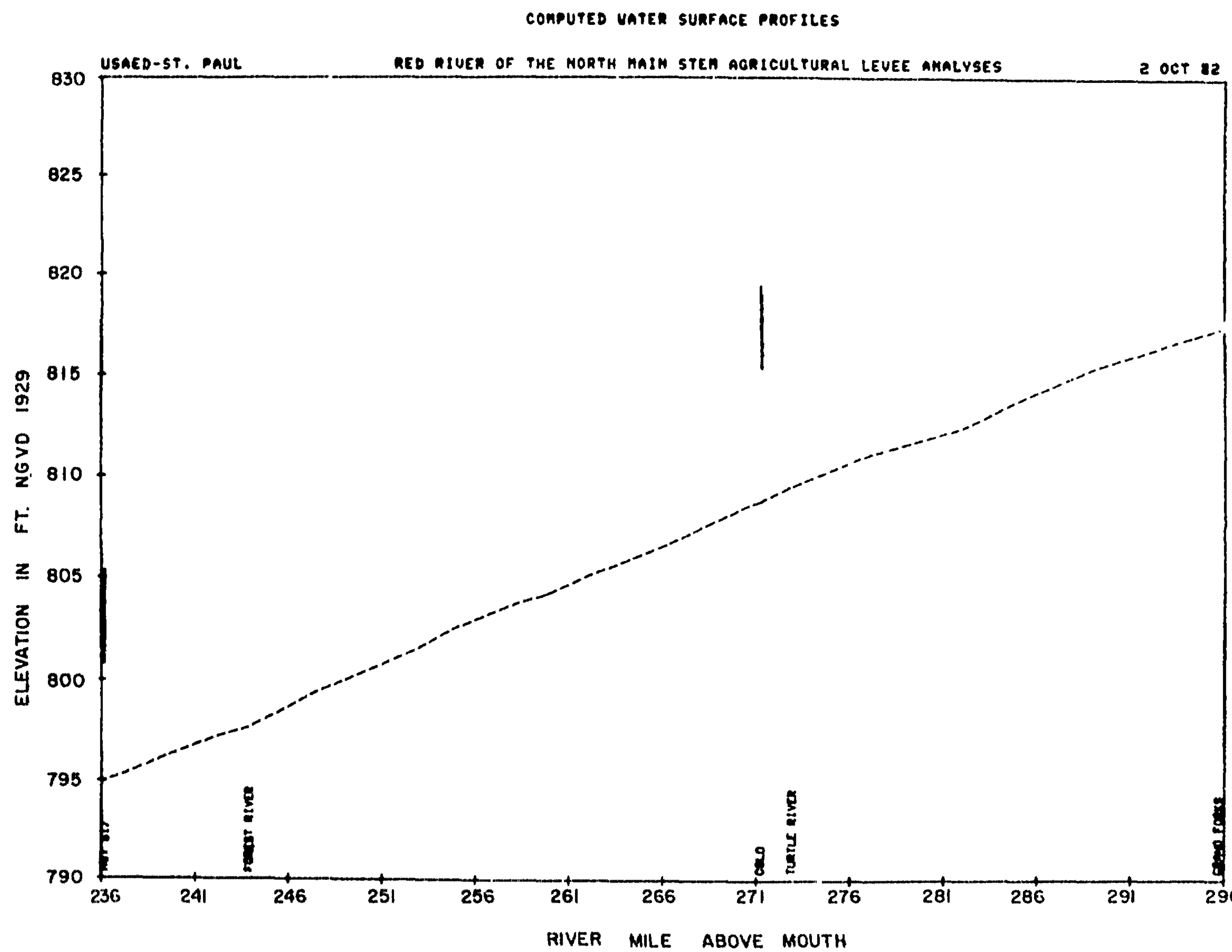
RIVER MILE ABOVE MOUTH

CASE 25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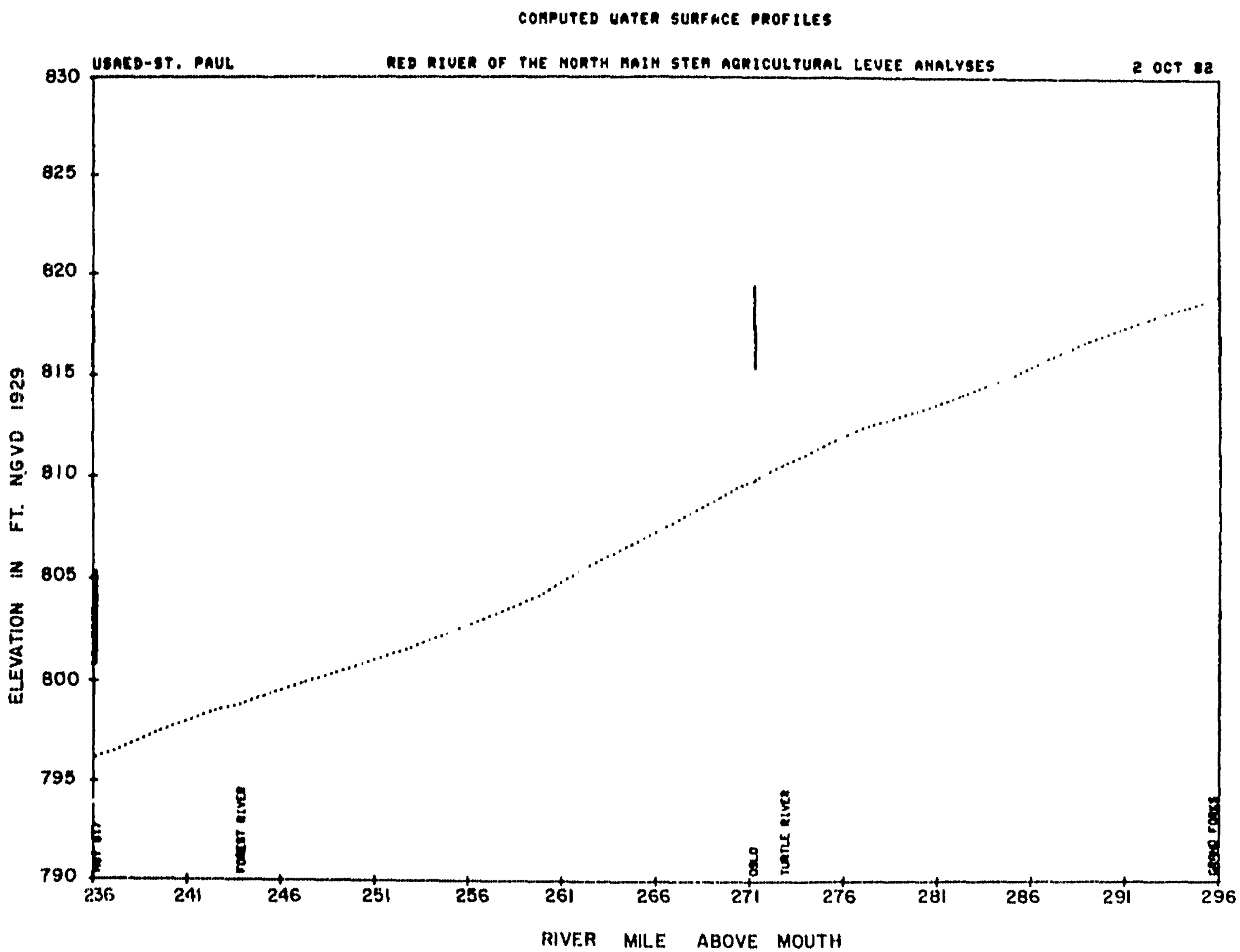
RIVER MILE ABOVE MOUTH

CASE 26



COMPUTED WATER SURFACE PROFILES
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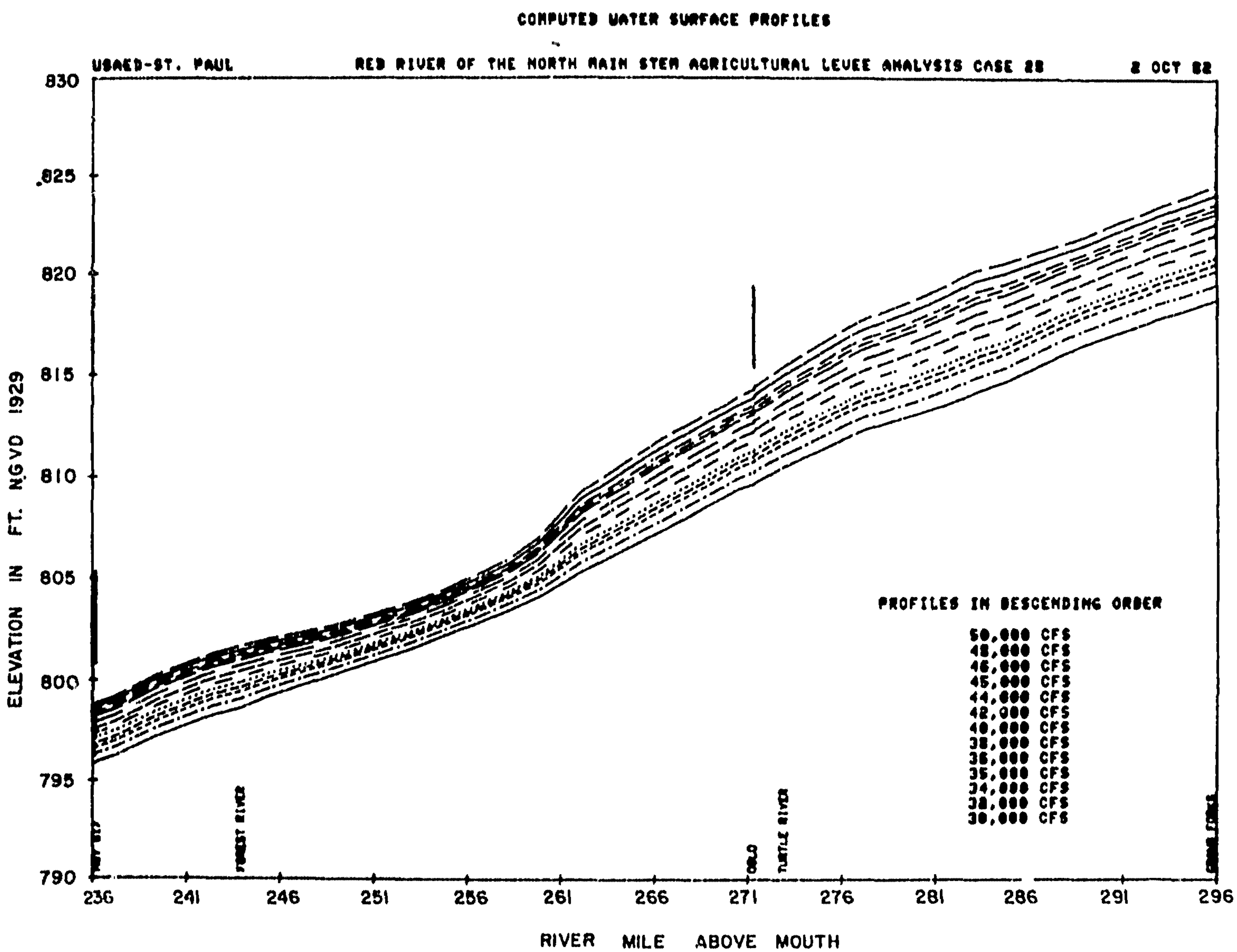
RIVER MILE ABOVE MOUTH

CASE 27


COMPUTED WATER SURFACE PROFILES
USAED-ST. PAUL
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PROFILES IN DESCENDING ORDER
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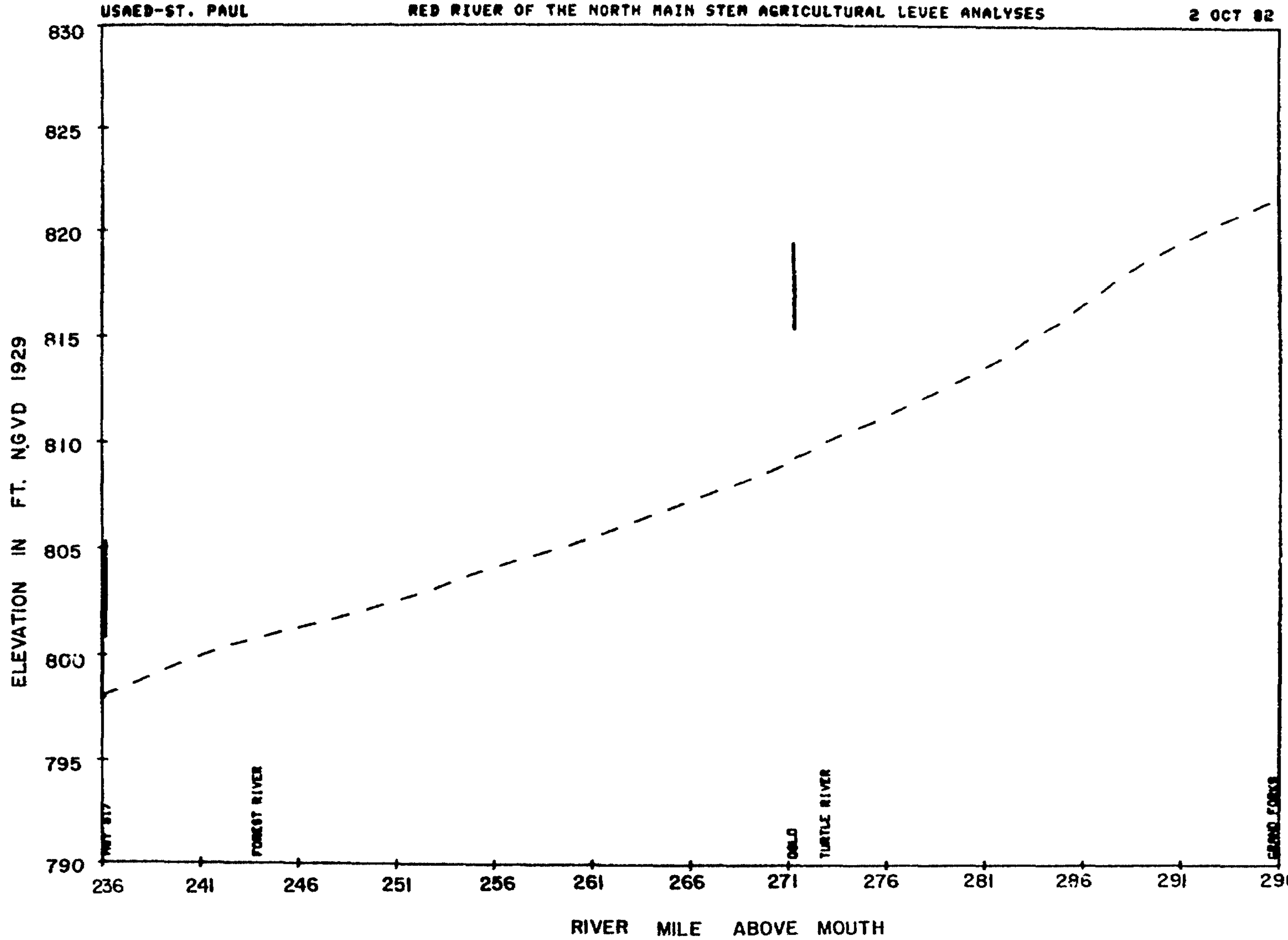
RIVER MILE ABOVE MOUTH

CASE 28

COMPUTED WATER SURFACE PROFILES

USAED-ST. PAUL   RED RIVER OF THE NORTH MAIN STEM AGRICULTURAL LEVEE ANALYSES   2 OCT 82



CASE 29

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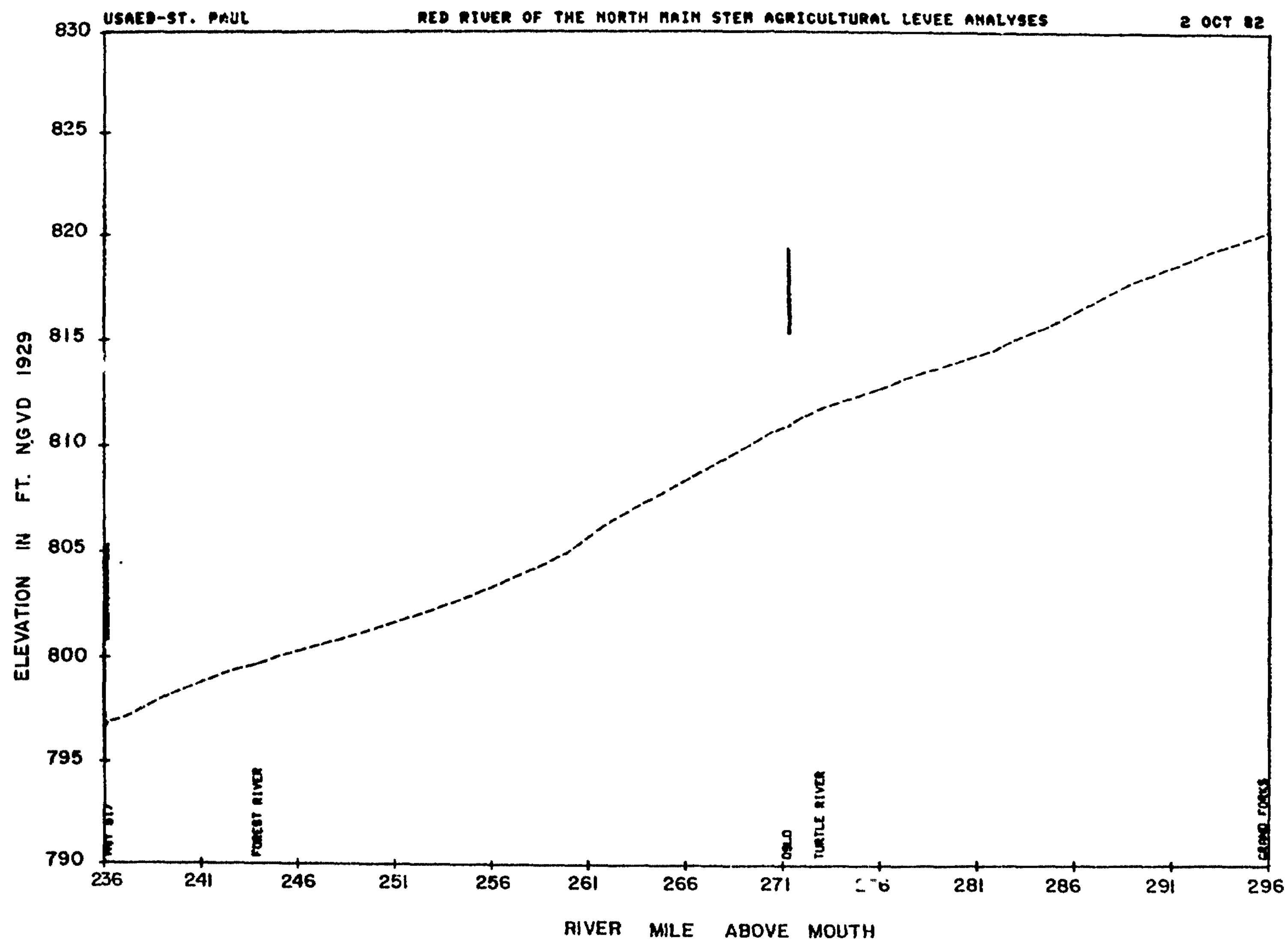
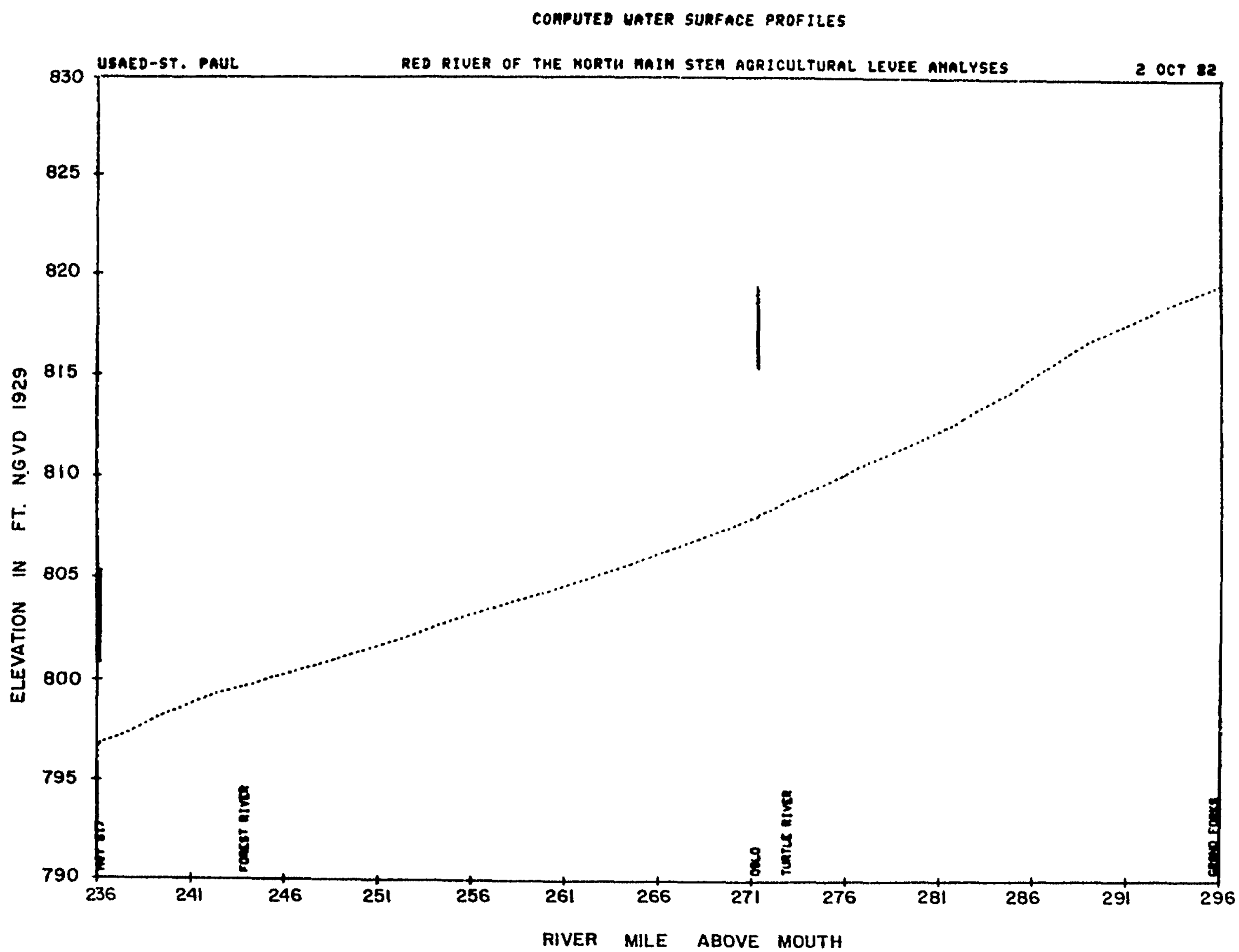


CASE 30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RIVER MILE ABOVE MOUTH
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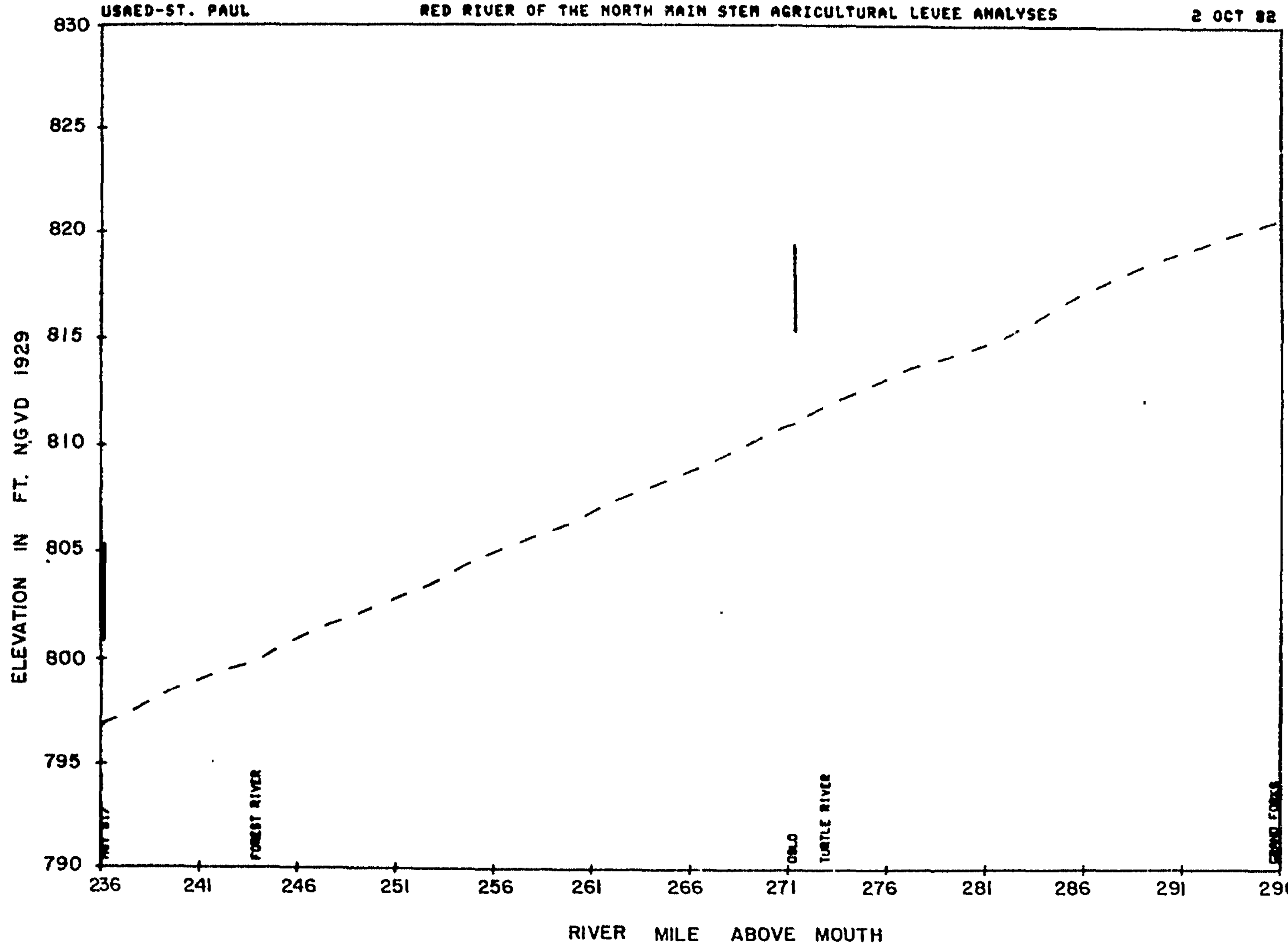
TURTLE RIVER
GRAND FORKS

CASE 31

COMPUTED WATER SURFACE PROFILES

USAED-ST. PAUL — RED RIVER OF THE NORTH MAIN STEM AGRICULTURAL LEVEE ANALYSES — 2 OCT 82



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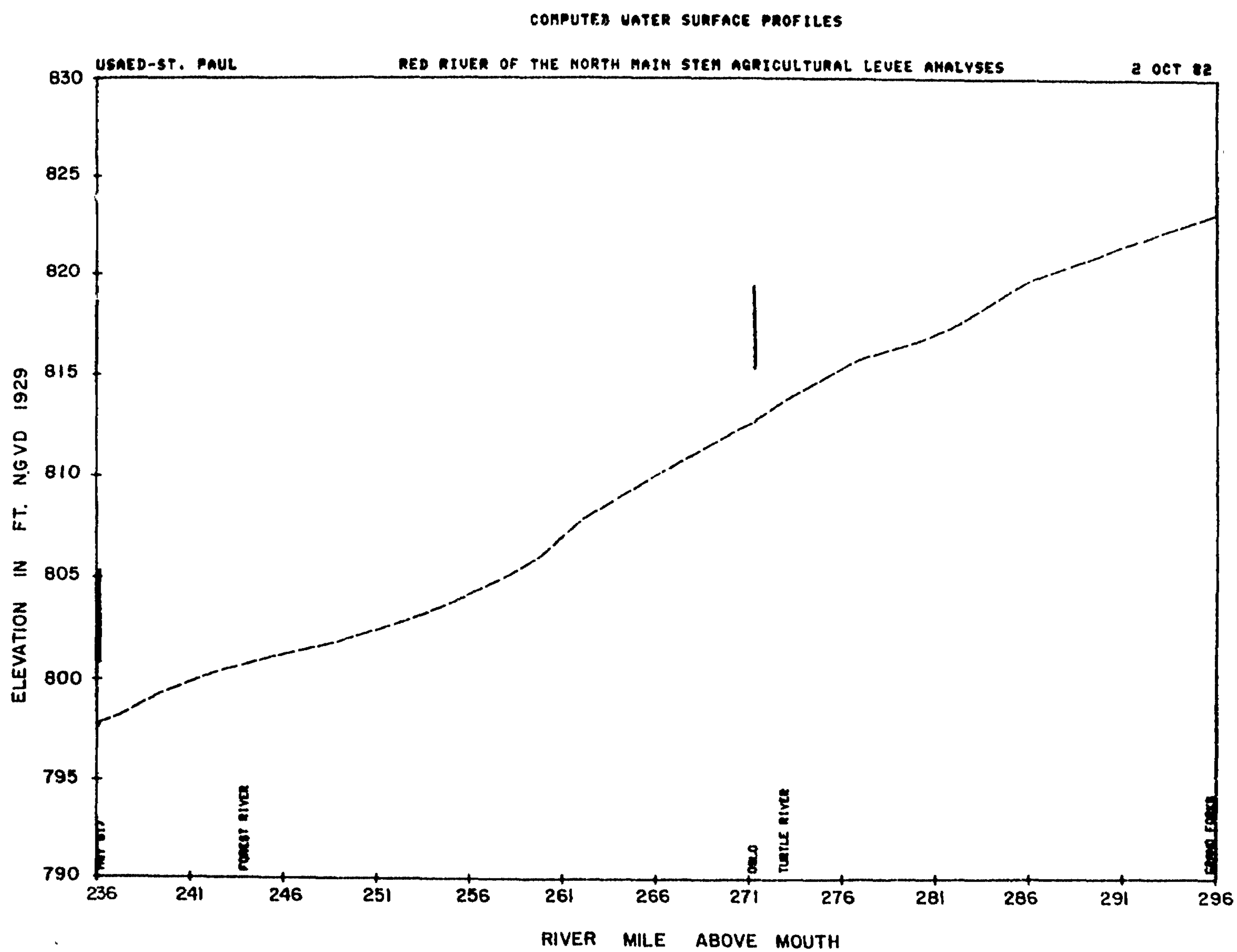
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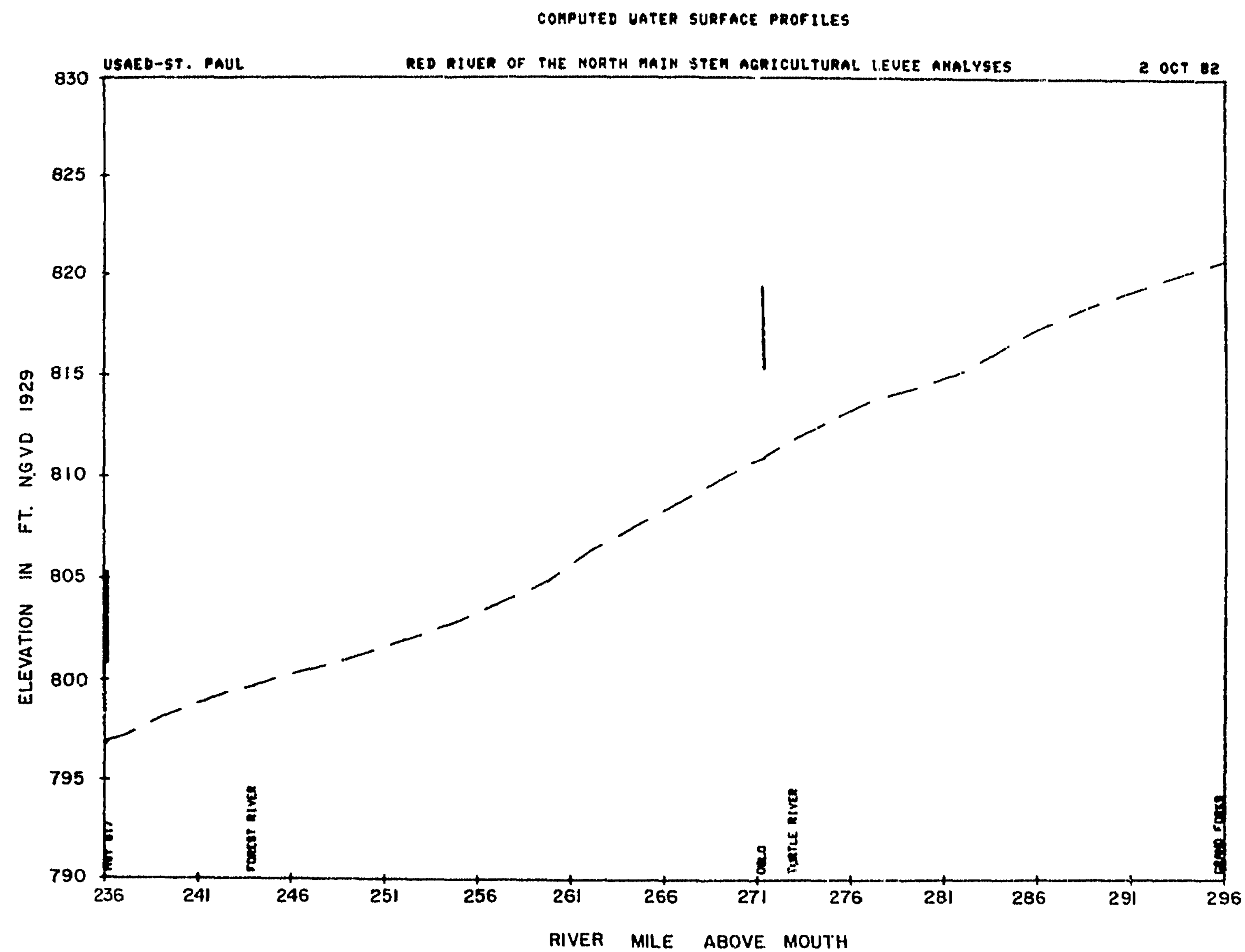
CASE 33



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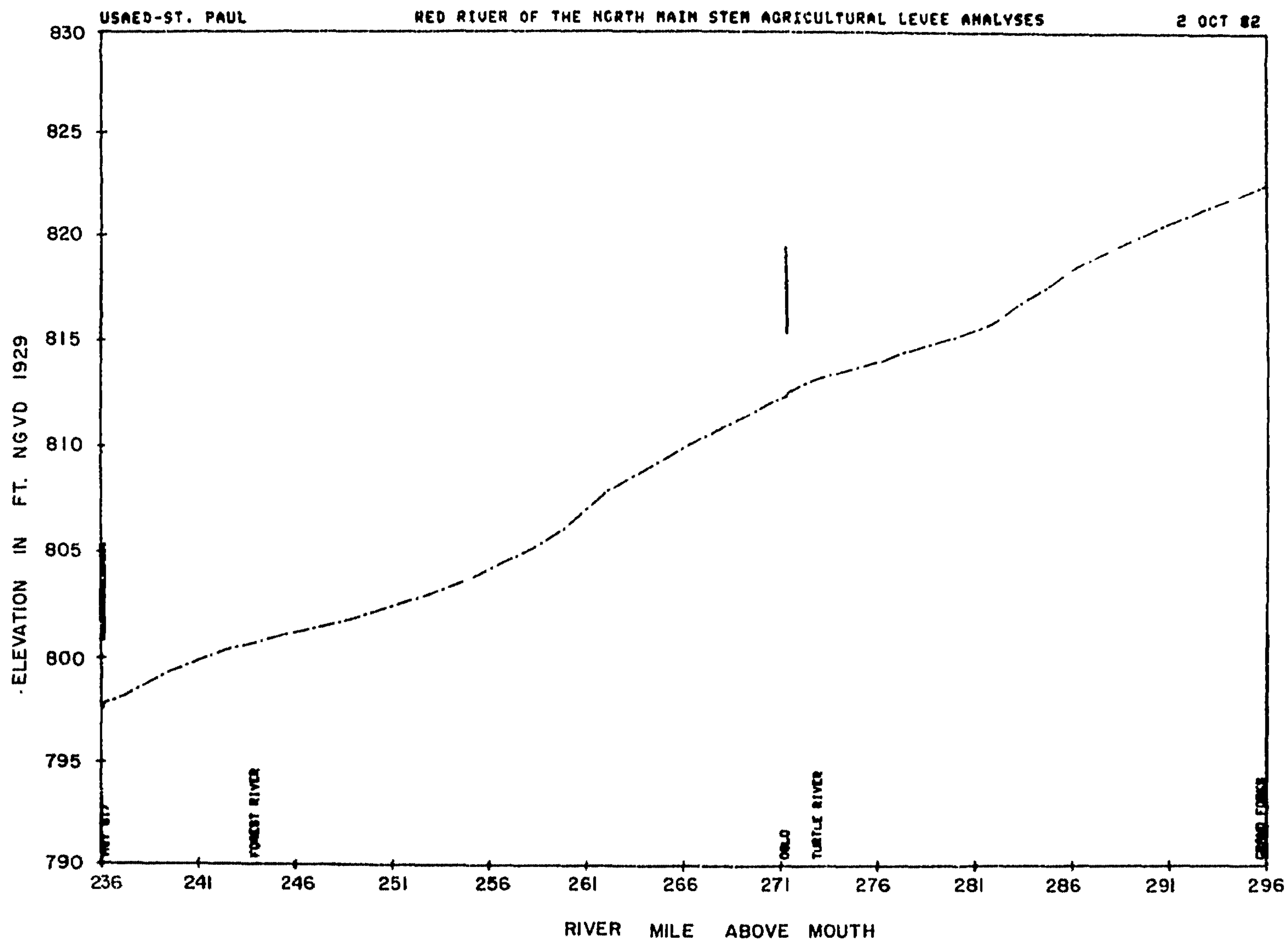
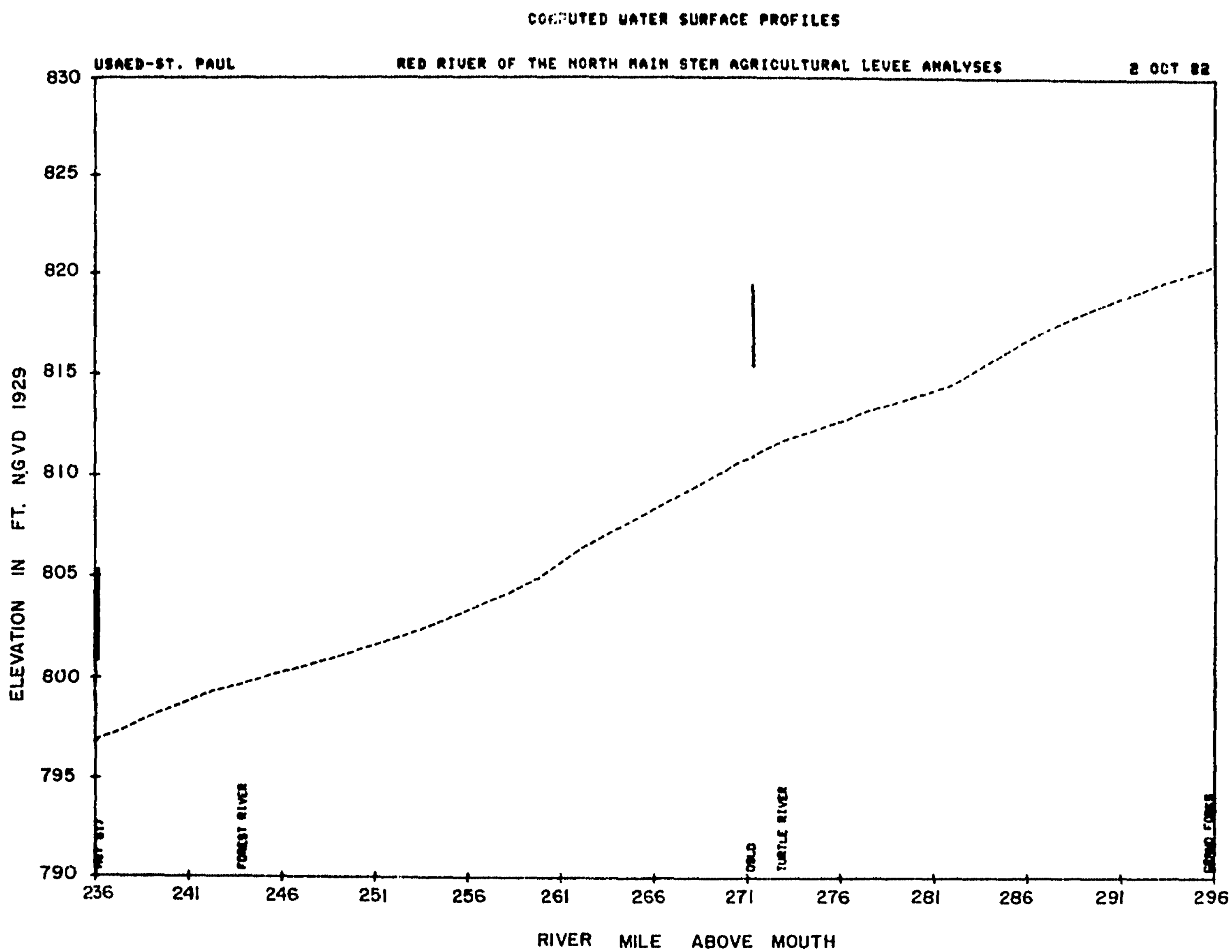
RIVER MILE ABOVE MOUTH

CASE 34

COMPUTED WATER SURFACE PROFILES



CASE 35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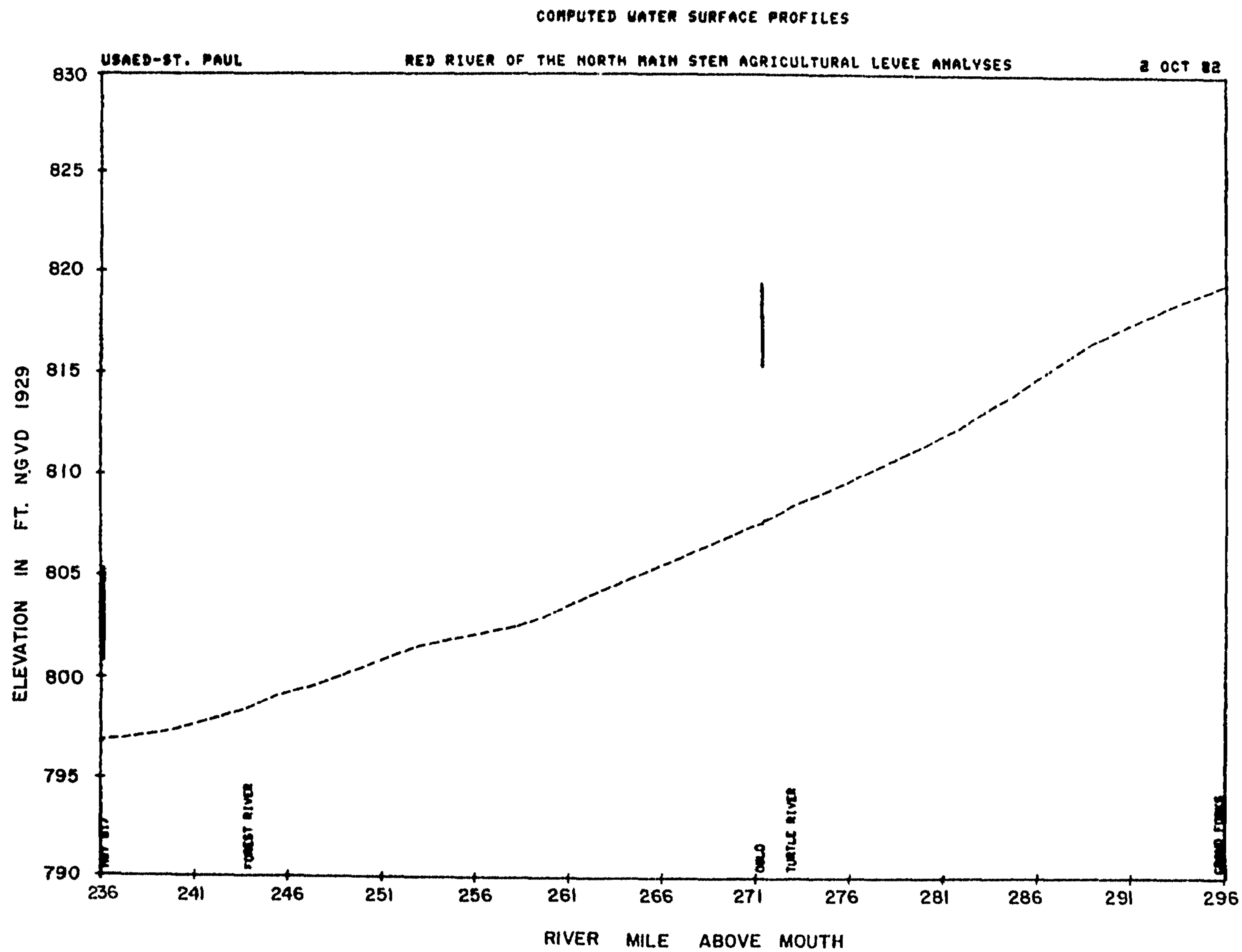
RIVER MILE ABOVE MOUTH

CASE 36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RIVER MILE ABOVE MOUTH

CASE 37

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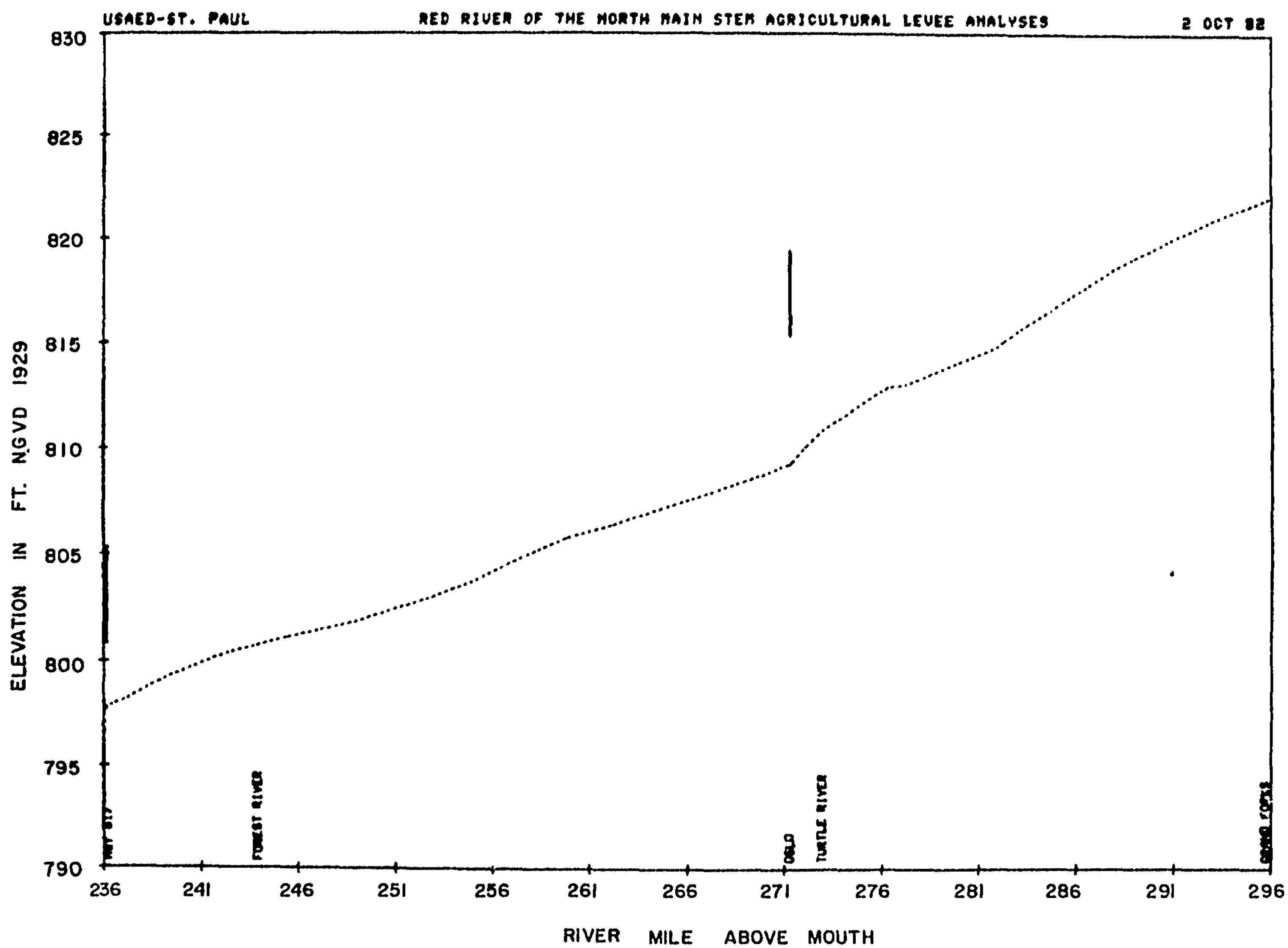

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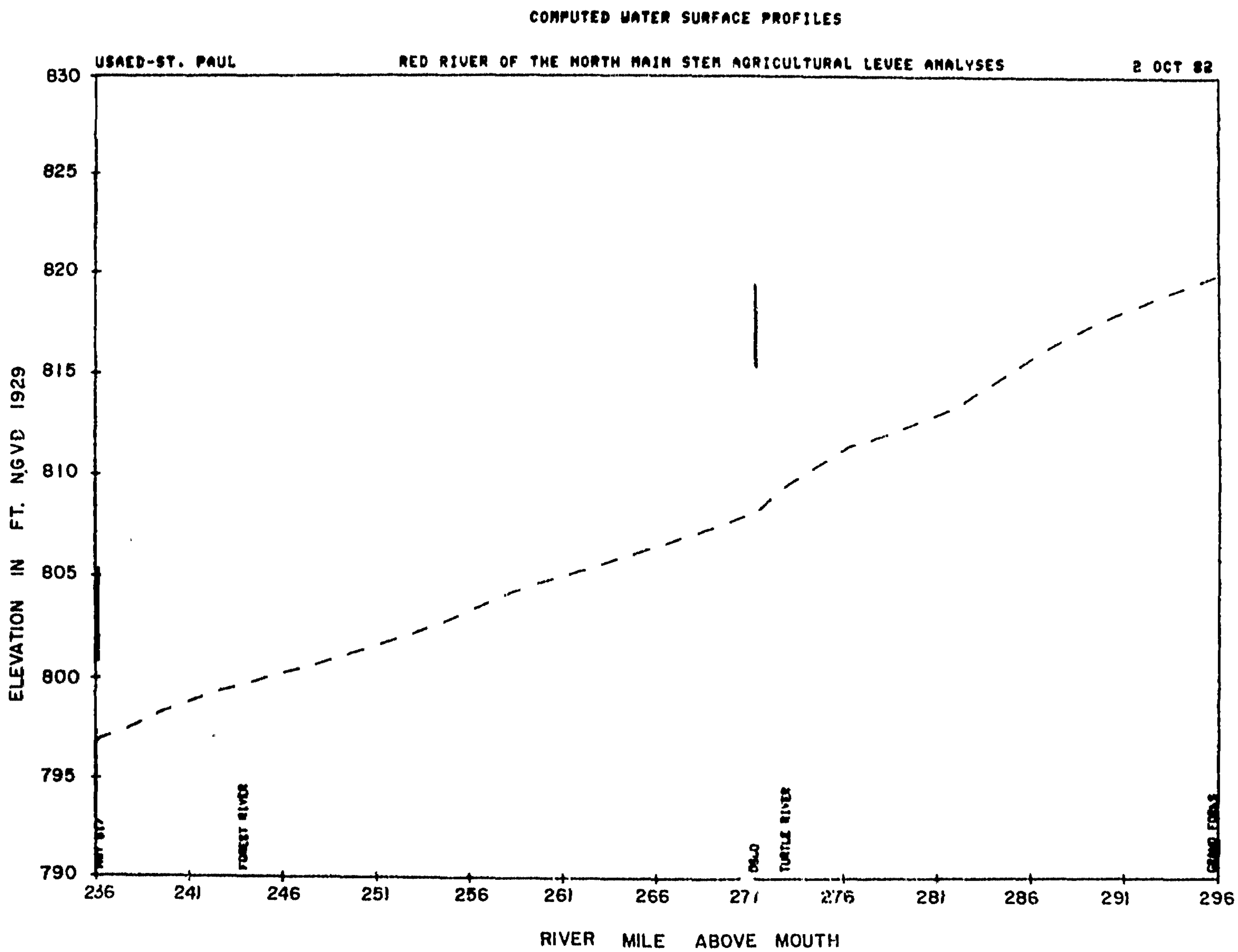
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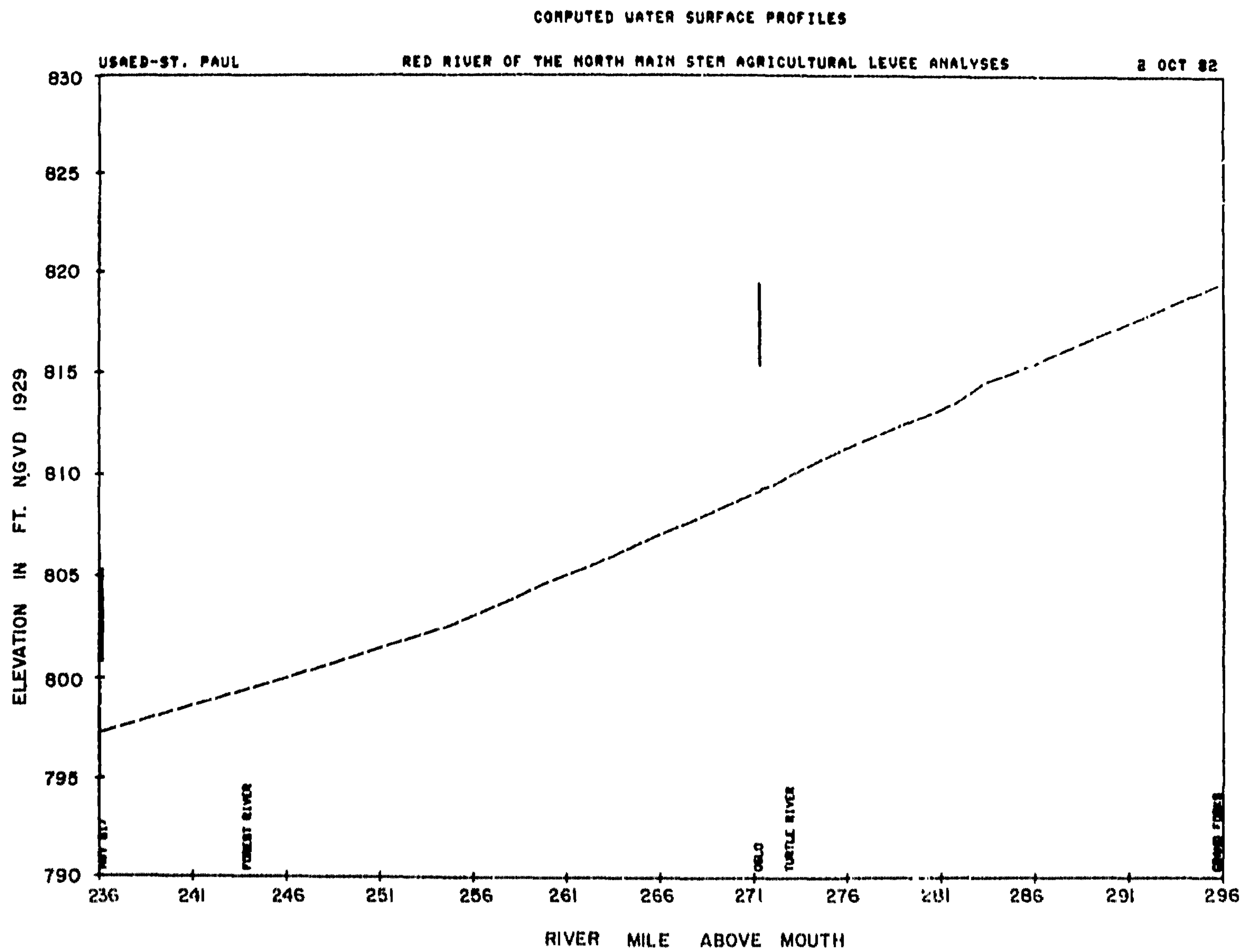
TURTLE RIVER
GRAND FORKS

CASE 39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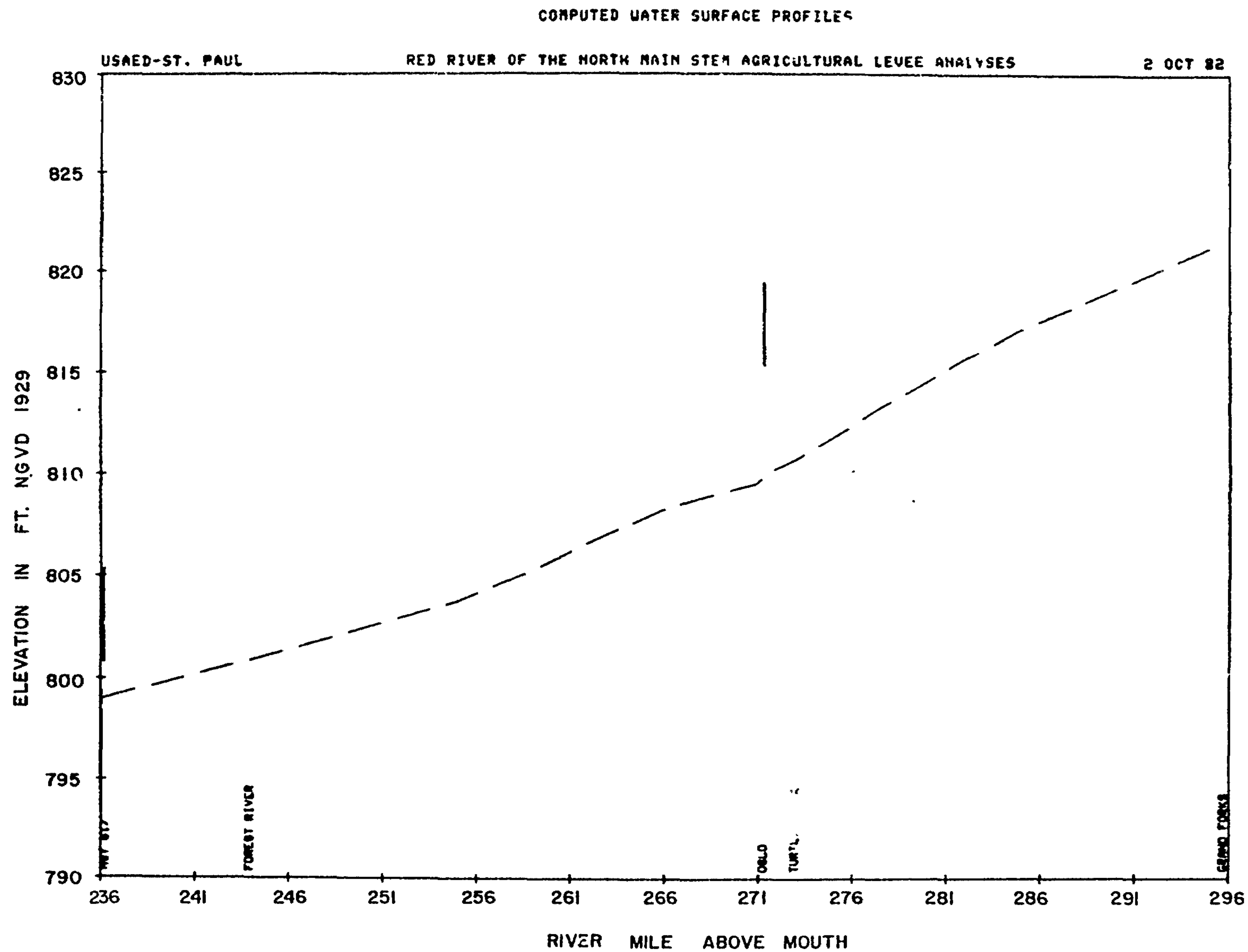
RIVER MILE ABOVE MOUTH

CASE 40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RIVER MILE ABOVE MOUTH

CASE 41

F. ENVIRONMENTAL EFFECTS OF EXISTING LEVEES AND PROPOSED MODIFICATIONS

1. Impacts on Fish, Wildlife, and Vegetation

a. Existing Condition. - The woodlands and brushy areas along the Red River are a valuable resource because of their value as wildlife habitat and their limited distribution. These areas provide den and nesting sites, winter and escape cover, and winter food for many resident and migratory animal species. The riparian areas also furnish a travel corridor for animals moving north and south along the Red River. Because of their importance, these areas should be protected, conserved, and enhanced whenever possible.

Riparian areas have been encroached upon over the years through the conversion of floodplain areas to agricultural uses. The development of agricultural levees has resulted in several direct and indirect environmental impacts. Levees have protected lands that may have previously been considered marginally suitable for agriculture, thereby allowing for more intensive farming.

Construction of the present levee system has resulted in the direct loss of trees and upland areas as land was cleared for levees. In some instances, wetland and wooded areas not prone to flooding after levee construction were converted to agricultural uses.

The current levee system, especially in those areas where levees flank both sides of the river, can decrease the cross-sectional area for flow and increase flood stages and velocities between the levees. Consequently, streambank erosion and channel scour may be somewhat aggravated in these areas during floods. Increased velocities may also increase sediment discharge. Areas immediately downstream of the levees may experience significantly more sediment deposition during floods as a result of the spreading out and change in velocities of floodwaters than they received before levee construction.

b. Proposed Modifications. - Plan A involves leaving the system in its present alignment. This base condition serves as a guideline for comparing the impacts of other alternatives.

Plan B involves the extension of levees in certain areas so that the same degree of protection is afforded to both sides of the river. The construction of approximately 24 miles of levee, most of which would be in North Dakota, would have several temporary impacts associated with construction, such as increased noise and air pollution. Turbidity of the river resulting from erosion at the construction site could also be temporarily increased.

Depending on the selected levee alignments, some floodplain vegetation may be removed during construction. In addition, streambank erosion may be aggravated during floods when flows are increased as a result of the decreased cross section.

Plan C involves the extension of the levee systems to provide an equal level of protection on both sides of the river and the realignment of some levee sections so that some of the oxbows are removed. Impacts of the levee extensions would be similar to those discussed for plan B.

Realignment of some levee sections could result in some minor adverse impacts associated with construction, such as temporary noise and air pollution and erosion at the construction site. However, the setback of some sections of the levee system could result in moderately beneficial impacts in those reaches where the area between the river and the realigned levee may not be suitable for continued agricultural use because of increased susceptibility to flooding. As a result, some of these areas may be allowed to revert to floodplain vegetation, which would create a more continuous wooded corridor. The value of these riparian areas as wildlife habitat would be increased.

A more acceptable alternative to landowners affected by any proposed realignment may be to use conservation tillage in the setback areas or to use these areas as pastureland or for hay production. Any of these practices would result in the establishment of a more protective ground cover, providing cover for wildlife and helping reduce erosion at the site and sedimentation at downstream points.

2. Recreation

See Appendix E.

3. Cultural Resources

a. Existing Conditions. - Currently, 13 known prehistoric archeological sites are within 1 mile of the Red River of the North between Grand Forks-East Grand Forks and the international border. However, on the basis of surveys conducted by Dr. Mike Michlovic (1981) along the Red River in Norman County, Minnesota (south of the present study area), an estimated 800 to 1,000 archeological sites exist within one-quarter mile of the Red River between its headwaters and the international border. Unfortunately, extensive surveys have not been conducted in the study area, so the exact number of sites is unknown.

Projecting from Michlovic's survey, it can be expected that prehistoric archeological sites will be located within one-fourth mile of the main channel of the river and within each oxbow, although sites have also been located along other rivers and streams in the floodplain. It is not expected that sites will be located more than one-fourth mile away from a main water source anywhere in the floodplain of the Red River.

The general type of archeological sites that can be expected to be located through systematic surveys in the study area are Late Woodland habitatian sites that are multicomponent and stratified. The majority of sites located in Norman County by Michlovic are ceramic bearing and contain typical Late Woodland triangular projectile points. However, this description is of the most common site type expected to exist in the study area and other sites, particularly deeply buried Archaic sites, probably also exist.

A systematic survey of historic sites has also not been completed. The Minnesota State Historic Preservation Office has begun a historic standing structure survey in the Red River Valley. This office began a survey of Polk County, Minnesota, a portion of which is part of the current study area, during 1981. Thus, the total number and type of historic sites in the study area are unknown.

Numerous historic sites are likely to be found along the Red River of the North because the river is the major geographic feature in the area and has been a transportation route and water source since prehistoric times. The kind of historic sites expected to exist include those associated with the protohistoric and historic American Indians, the fur trade, early immigration, and settlement including those associated with the Red River oxcart trails and bonanza farming. In addition, the many communities located along the Red River probably also contain numerous sites of not only historic but architectural significance as well.

Three main destructive forces appear to be affecting archeological and, to a certain degree, historic sites along the Red River: intensive agriculture erosion, and flooding. Probably the major force is cultivation which displaces cultural material and, depending on the depth of plowing, can completely destroy the entire cultural context of a site. Although flooding and the subsequent buildup of deposition buries sites and renders them inaccessible for study, it also in many cases buries them beyond the reach of the plow, thus protecting them to a certain degree. Sites are also being destroyed by erosion and bank slumping. Because of their location within the oxbows, they are continuously cut by the meander of the river.

b. <u>Proposed Modifications</u> - All of the proposed plans will affect cultural resources along the Red River of the North to varying degrees.

Plan A would have the least severe impacts on cultural resources because the major impacts associated with this plan occurred during the original construction, particularly if the levees were constructed from level scrapings. If sites do exist within one-fourth mile of the river, the present location of these levees probably has already disturbed those sites located along its route. Thus, no additional impacts can be expected from implementation of this plan.

The impacts to cultural resources associated with Plans B and C are very similar. Both plans involve the construction of levees within one-fourth mile of the river. This area has the highest potential for the existence of archeological resources along the Red River. Plan C could affect sites located between the levee and the river that would be disturbed by additional flood deposition, although the possibility of reduced cultivation in these areas could have a positive effect on archeological sites. Historic standing structure resources would probably not be affected by either of these plans because it is not anticipated that any structures would be altered or removed by implementation of any of these plans.

The fill sources for construction of the levees in Plans B and C could also affect cultural resources. These impacts could result from either the level scraping of fields for material or excavation of borrow pits for fill.

All probable impacts are based on limited information. Cultural resource surveys have not been conducted in the area, and, until the exact number, type, and location of sites are known, a detailed determination of the impacts on cultural resources is not possible.

G. CURRENT STATUS OF MODIFICATION PLANS

As of August 1981, the attempt to develop a compromise corrective plan for the existing levees at the local level has not been successful. A joint meeting between the Middle River-Snake River Watershed District and the Grand Forks and Walsh County Water Management Boards was held in April 1981. The local agencies presented their formal positions on a corrective plan. These positions are summarized briefly below.

Middle River-Snake River Watershed District Proposal:

- Both sides should be allowed to build levees providing 43,000-cfs protection.
- Some realignment of levees on both sides of the river should be done similar to Alignment C.
- All structures within the levee system should be brought into general conformance with the intent of the levee system.
- Case 4 should in theory represent this proposal, but the Case 4 profile is too low at the north end and too high near Oslo. The 1978 high-water profiles with some minor modifications may more accurately reflect this proposal. (Note that Case 41, while being the best estimate for 43,000-cfs protection on the Minnesota side, does not assume equal protection on both sides of the river.)

Grand Forks and Walsh County Water Management Boards Proposal:

- The level of protection provided by the existing levees shall not exceed 35,000 cfs, allowing the top of levee elevation to be at or near the observed summer 1975 flood profile.
- The North Dakota levee system will not be substantially raised or extended.
- Levee realignment will be considered where hydraulically appropriate.
- The two county boards expressed willingness to compromise to 39,000-cfs protection.

The principal differences between the two proposals are the level of protection and the status of any future modifications to the North Dakota levees. At the meeting, all three boards concluded that a corrective plan acceptable to local landowners on both sides of the river could not be agreed upon. The consensus at the meeting was that a compromise was not possible at the local level and that a corrective plan may have to be determined by the courts. The problem has been referred to the State level for resolution.

In October 1981, the States held a meeting to discuss the problem. In Appendix F (Correspondence) are included two letters between the Minnesota Department of Natural Resources and North Dakota State Water Commission that outline these agencies' positions on the agricultural levees. No agreement was reached at this meeting. Litigation was initiated in June 1982.

H. HYDRAULIC EFFECTS OF OTHER STRUCTURES IN THE FLOODPLAIN

While the local water management agencies have been examining the effects of the agricultural levees, they have pointed out that other structures in the floodplain have the potential to increase floods. The approach road embankments for the railroad and highway bridges at Oslo were singled out as causing significant problems. Therefore, we have analyzed the hydraulic effects of these structures for the 1-percent chance flood without agricultural levees condition. The following analysis is accurate only for the 1-percent chance flood; different stage increases may occur for different frequency floods.

1. Bridges and Approach Roads

In general, the bridges have been raised above the level of the 1-percent chance flood and do not significantly affect flood stages. The approach roads, however, are typically on top of raised embankments and block flows in the overbank areas. The stage increases at each bridge over the Red River are discussed below. Table 15 summarizes data on the bridges. Profiles of the approach roads were obtained from the Minnesota Department of Transportation, North Dakota State Highway Department, and separate surveys. The analysis below considers removal of the bridge structure and all sections of the approach above the level of the 1-percent chance flood.

a. Soo Line Railroad Bridge at Oslo (RM 271.24) - This bridge raises the stage at Oslo 0.5 foot for the 1-percent chance flood under the assumption that the Federal project and existing highway bridge are in place. At a distance 7 river miles upstream of the bridge, a stage increase of 0.1 foot or less was computed.

b. Minnesota Highway 1/North Dakota Highway 54 Bridge at Oslo (RM 271.20) - For the 1-percent chance flood, the highway bridge at Oslo raises the water surface elevation 0.15 foot compared to a no-bridge condition. At a distance of 8 river miles upstream, less than a 0.1-foot stage increase is seen. The existing railroad bridge and Federal flood protection works are assumed in place for both the with and without bridge conditions.

If the highway and railroad bridges were removed (with the Federal project in place), the stage at the upstream side of the railroad bridge could be lowered 0.76 foot for the 1-percent chance flood compared with existing conditions without the agricultural levees. At a distance of approximately 8.5 river miles upstream, less than a 0.1-foot difference was computed.

c. Minnesota Highway 317/North Dakota Highway 17 Bridge (RM 236.07) - The Highway 317 bridge, east of Grafton, North Dakota, is the downstream limit of the agricultural levees. The North Dakota highway approach to the bridge has an average top of road elevation of 804.2 feet. The 1-percent chance flood elevation at the bridge is 800.73. All of the floodwaters are passed through the bridge and across Minnesota Highway 317 to the east. Removing the existing bridge and approaches would lower the 1-percent chance flood profile at this location 0.1 foot.

A comparison of discharge-measurement notes taken during the 1979 flood and May 1978 bridge sketches indicates that, on the average, the channel bottom can change 2 to 3 feet under the bridge. This change is caused by scour during the flood and aggradation during normal and low flows. The channel bottom profile measured during the flood peak was 2 to 3 feet lower than that shown on the surveyed cross sections. A similar condition was noted at the Minnesota Highway 1 bridge at Oslo.

d. Minnesota Highway 11/North Dakota Highway 66 Bridge at Drayton, North Dakota (RM 206.70) - For the 1-percent chance flood, the existing bridge and approaches raise the water surface elevation a computed 0.05 foot compared with a no-bridge condition. This relatively small effect is, in large part, due to the conveyance provided by the North Dakota overbank and a clearance of 1.6 feet between midspan low steel and the 1-percent chance flood profile.

The North Dakota Highway Department has proposed a 6-foot raise of the North Dakota approach. This raise would increase the stage of the 1-percent chance flood 0.3 foot. Channel velocities through the bridge would increase from 3 to 4.5 fps. The proposed road raise completely blocks the overbank on the North

Dakota side. For existing or proposed conditions, no overflow occurs on the Minnesota side of the bridge because the approach and road profile is between 1 and 5 feet above the 1-percent chance flood elevations. The backwater effect from the road raise was computed to extend 8.5 river miles upstream of the Highway 66 bridge where the difference was less than 0.1 foot.

e. <u>Minnesota Highway 175/North Dakota Highway 5 Bridge (RM 179.55)</u> - This bridge has no significant impact on flood stages. With the bridge in place, a 0.01-foot stage increase was computed compared with a no-bridge condition for the 1-percent chance flood. The bridge is perched and has low approaches which allow floodwaters to be carried in the overbanks.

f. <u>Minnesota Highway 171/North Dakota Highway 59 Bridge at St. Vincent, Minnesota (RM 158.11)</u> - For the 1-percent chance flood, the Highway 171 bridge at Pembina, North Dakota, has a computed stage increase of 0.05 foot compared with a no-bridge condition. At a distance of 5.6 river miles upstream, the difference is 0.01 foot or less.

g. <u>Bridges at Emerson (RM 154.73, 154.59)</u> - The highway and railroad bridges at Emerson increase the stage of the 1-percent chance flood 0.4 foot at Emerson compared to a no-bridge condition. At the international border, the increased caused by the bridges was computed to be 0.35 foot. At Pembina-St. Vincent, the stage increase was computed to be 0.3 foot.

BRIDGE DATA INVENTORY

TABLE 15

BRIDGE LOCATION	RIVER MILE	CROSS SECTION NUMBER	NET WATERWAY OPENING	THALWEG ELEV	LOW CHORD ELEV	LENGTH IN FEET	PIERS QTY WIDTH IN FT
CANADIAN NAT'L RR BR AT EMERSON	154.59	.2	15220	736.5	796.0	500	2 @ 10 1 @ 30
PROVINCIAL HWY 75 AT EMERSON	154.73	.5	18880	740.5	786.2	740	2 @ 6 7 @ 3
MINN HWY 171 BR AT PEMBINA	158.11	4.1	24770	736.0	791.7	768	2 @ 8
ND 5-MN 175 HWY BR WEST OF HALLOCK	179.55	1310	38170	741.3	800.1	1310	3 @ 5 14 @ 3
ND HWY 66 BR AT DRAYTON, ND	206.70	2910	29180	754.7	802.1	1056	2 @ 6 6 @ 3
MN HWY 317 BR EAST OF GRAFTON	236.07	4310	11590	75910	800.8	410	1 @ 5.2
MINN HWY 1 BR AT OSLO, MINN	271.20	5810	20280	762.6	815.4	790	3 @ 6 4 @ 3
SOO LINE RR BR AT OSLO, MINN	271.24	5910	13480	768.4	815.3	580	1 @ 29.2 1 @ 12.7 1 @ 11 1 @ 7 20 @ 1

2. Judicial Ditch Spoil Banks

Two large drainage ditches enter the Red River south of Oslo: Minnesota Judicial Ditch 1 at river mile 276 and Minnesota Judicial Ditch 75 at river mile 282. Local interests have suggested that the substantial spoil banks on the east-west ditches obstruct flood flows, increasing flood stages on the upstream side of the ditches.

a. Minnesota Judicial Ditch 1 has a relatively small impact on water surface profiles. The computed stage for the 1-percent chance flood is reduced 0.05 foot if the spoil bank is removed. The downstream side of the spoil bank is affected by backwater stages at Oslo and has less than one-half foot clearance above the 1-percent chance flood profile.

b. Minnesota Judicial Ditch 75 has some impact on the 1-percent chance flood profile. If the spoil bank were removed, stage reduction is computed to be 0.18 foot. At a distance approximately 3.5 river miles upstream, less than a 0.1-foot stage reduction is realized. Aerial photos of the 1969, 1975, 1978, and 1979 floods illustrate how this spoil bank blocks floodwaters in the Minnesota overbank area. The spoil bank acts as a levee and prevents overbank flows. Water ponds upstream of the levee for a distance of 2 to 3 miles and east of the Red River a distance of 2 to 3 miles. This spoil bank does not affect stages at Grand Forks because the computed stage increase is only 0.01 foot.

3. Federal Flood Control Project at Oslo

Analysis of the Oslo levee was completed for several different conditions for the 1-percent chance flood:

a. For the existing highway and railroad bridges in place and no agricultural levee, the stage increase caused by the Federal project was computed to be 0.06 foot at the gage site and 0.22 foot at the upstream side of the railroad bridge.

b. If the Federal project and the Soo Line Railroad bridge were removed, the stage would be reduced 0.58 foot at the upstream side of the bridge.

c. If the Federal project, Minnesota Highway 1 bridge, and the Soo Line Railroad bridge were removed, the stage would be reduced 0.77 foot.

d. Computations were made assuming no bridges at Oslo. With this assumption, profiles were computed for both with and without the Federal project. Slight stage increases were computed at Oslo, ranging between 0.01 and 0.09 foot. These results agree with hand computations done in 1968 for the Pembina and Oslo projects to determine the effects of ring levees in a broad floodplain.

II. FEASIBILITY ANALYSIS OF ALTERNATIVES

A. BACKGROUND

The Red River Main Stem Study began in 1977 as an interim feasibility investigation under the various authorities directing the Corps to pursue water resource investigations of the Red River of the North and its tributaries. The purpose of this study was to examine alternatives that could alleviate flooding on the Red River main stem, with special emphasis on agricultural levees. Stage 1 of the study was completed in 1978. It identified the problems and needs of the main stem study area (essentially the regional floodplain) and laid out a plan for further studies. During Stage 2, a broad range of alternatives that could reduce main stem flooding were considered, including many alternatives outside of the main stem study area. These alternatives were screened by a group of Federal and State water resource experts for their potential effectiveness in reducing main stem flooding. Subsequent evaluation of the screened alternatives led to the following conclusions:

- The alternatives outside the main stem study area, although they had the potential to reduce main stem flooding, were not appropriate given the main stem study funding limits. These alternatives would be considered under the preliminary basinwide review study in 1980 (subsequently completed under contract with the Gulf South Research Institute).

- The alternatives recommended for continued study on the main stem were agricultural levees; bridge, roadway, and drain modifications; channel modifications; and diversions.

- Because local interest was strong, the alternative of ring levees around individual farmsteads should be added.

- The evaluation of all roads and drains within the study area was beyond the scope and funding of the study. Therefore, only modifications to the bridges over the Red River and their associated approach roads would be considered.

Stage 2 was completed in October 1979. At this point, the St. Paul District recommended that the study be converted to an engineering information study, stressing the hydrologic and hydraulic data and analyses needed by the States and local interests to resolve the problem of the existing agricultural levees. This recommendation was supported by the States of Minnesota and North Dakota and was approved by the North Central Division of the Corps of Engineers in January 1980. Studies since then have concentrated on the effects of the existing agricultural levees and proposed modifications to those levees. Analysis with the HEC-2 and HEC-5 computer models has been limited to the Grand Forks to Canadian border reach. The HEC-2 water surface profile model is operational only for this reach; calibration of the reach upstream of Grand Forks has been delayed in favor of extensive analysis of the levees in the Grand Forks to border reach.

B. FIVE ALTERNATIVES CARRIED FROM STAGE 2

While the principal recommendation of the Stage 2 report was to convert to an engineering information effort with emphasis on the existing agricultural levees, the report also identified five alternatives on the main stem that might be effective. These five alternatives are agricultural levees, bridge/approach road modifications, channel modifications, diversion channels, and farmstead ring levees. They are discussed below.

1. Agricultural Levees

Because the existing levee system is partially successful, particularly in more frequent floods, there has been interest in the potential for agricultural levee construction in the rest of the Grand Forks to international border reach. Any new levee system would have to comply with the States' criteria. A preliminary cost estimate for agricultural levees that would provide 100-year protection and meet the criteria was made as part of the main stem subbasin report of the Red River of the North Preliminary Basin-Wide Review Study (St. Paul District/Gulf South Research Institute, 1980). The estimated benefit-

cost ratio for this levee system was 0.67, indicating that this alternative was not feasible by Corps standards. That still leaves two questions unanswered:

a. Would agricultural levees be feasible if constructed to local rather than Corps standards and using local costs for construction?

b. Would levees providing a lesser degree of protection and complying with the criteria be more feasible than levees providing 100-year protection?

This report will address those two questions in greater detail.

2. Bridge/Approach Road Modifications

As stated in section I.F. of this report, the bridge structures are generally above the level of the 1-percent chance flood and do not significantly affect flood stages for the 1-percent chance flood. The bridges may have a greater impact on flood stages if future improvements of the approach roads were to prevent or reduce over-the-road flows. The approach road embankments do affect flood stages, but the maximum increase in the stage of the 1-percent chance flood is 0.5 foot (immediately upstream of the Soo Line Railroad bridge at Oslo). In other words, this bridge/approach road complies with the States' criteria. For all of the other bridge/approach combinations, the stage increase is less than 0.5 foot, and the stage increases dissipate upstream rather rapidly. While we have not done detailed cost and benefit calculations for modifying the approach roads, in our best judgment, the costs for modifying these embankments to pass flood flows and still maintain traffic use are likely to exceed the limited benefits to be derived from such modifications.

As an example, the bridges and approach roads for Minnesota Highway 1/ North Dakota Highway 54 and the Soo Line Railroad at Oslo were analyzed to determine the stage reductions that could be achieved by approach road modifications. The approaches to the highway bridge were lowered on both

sides of the river by 2 feet and 4 feet to simulate a "Texas crossing." The embankment for the Soo Line Railroad was modified to include additional waterway capacity on the left (i.e., North Dakota) overbank. An area of approximately 116,000 square feet was excavated to an elevation of 783.5 (from a top of bed elevation of 810.5) over a distance of 4,300 feet. Because the top of rail must remain at its present elevation to preserve the railroad grade excavating such a large waterway opening would require a bridge or causeway at this location. These modifications were computed in various combinations as listed in table 16.

Table 16 - Effects of approach road modifications at Oslo

Amount approaches lowered	Soo Line Railroad bridge with excavation	Stage reduction for the 1-percent chance flood (feet)
2 feet	No	0.08
	Yes	0.36
4 feet	No	0.15
	Yes	0.44

Obviously, very substantial and costly changes must be made to these approach roads to reduce some of the 0.76-foot stage increase caused by this combination of structures at Oslo.

3. Channel Modifications

Channel improvement to contain the 10-percent chance flood for the Grand Forks to international border reach was evaluated in the main stem subbasin report of the Red River of the North Preliminary Basin-Wide Review Study (St. Paul District/Gulf South Research Institute, 1980). The benefit-cost ratio for this alternative was calculated to be only 0.31. In addition to the lack of economic feasibility, the channel modification alternative has two other serious drawbacks:

a. Channel modification has moderate to severe adverse environmental impacts.

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b. The Soil Conservation Service (SCS) is also investigating farmstead ring levees for Grand Forks County, North Dakota, under the Resource Conservation and Development program. The SCS has already completed surveys of some of the eligible farmsteads, and, if higher-level approval and funding are obtained, construction could begin in 1982.

On the basis of preliminary results from these two studies, farmstead ring levees are probably feasible elsewhere along the Red River main stem. These two types of studies are initiated in response to local requests.

C. FEASIBILITY OF AGRICULTURAL LEVEES USING LOCAL COSTS AND CONSTRUCTION STANDARDS

The feasibility of agricultural levees that protect from the 100-year (1-percent chance) flood and conform to the States' criteria was estimated using local construction standards and costs rather than Federal construction standards and costs. The HEC-2 model generated the levee setback at each cross section by encroaching equally from both sides into the floodplain until the water surface matched the elevation of the 100-year flood plus one-half foot. Comparing this elevation, which represents the necessary top of levee elevation, with the ground elevation along the levee alignment provides the height of the levee. The average levee setback and height, appropriate levee length, and land area riverward of the levees are broken down for the six reaches in table 17.

Table 17 - Data for 100-year levees

Reach	Average levee height (feet)(1)		Average levee setback (miles)		Approximate levee length (miles)(2)		Area riverward of levee (square miles)	
	ND	MN	ND	MN	ND	MN	ND	MN
1	7.6	5.0	0.4	0.2(3)	6.6	6.9	3	7
2	4.7	8.0	1.9	1.4	11.0	10.4	25	13
3	3.9	4.3	2.3	2.0	6.4	7.6	14	12
4	5.8	5.6	1.5	2.2	8.2	9.2	19	34
5	5.0	6.4	1.0	2.1	9.4	12.5	14	24
6	6.6	6.0	1.3	1.9	31.7	37.9	41	60

(1) The levee top elevation at any point along the river is equal to the elevation of the 100-year flood plus 0.5 foot and levee top elevations are equal on both sides of the river. Thus, differences in average levee height reflect differences in average ground elevation.

(2) This length represents main stem levees only; it does not include tributary levees.

(3) The average setback here is biased toward a less than representative distance because of the confluence with Grand Marais Creek.

Standard engineering design was assumed for the levees; that is, 1:3 side slopes, 10-foot top width, and seeding to protect against future erosion. Interior drainage problems were handled in a very approximate manner by installation of flap-gated culverts approximately every one-fourth mile of levee length. All costs were based on Corps estimates of the costs necessary for local people to acquire the goods and services for levee construction.

The presence of tributary streams complicates the construction of agricultural levees on the main stem. This problem is apparent in the reach of existing levees on the North Dakota side where incoming tributaries create gaps in the levee system through which Red River backwater can readily pass. For this feasibility estimate for 100-year levees, tributary levees were extended from the tributary mouth up to a point where ground surface elevation equaled the 100-year plus one-half foot water surface elevation at the tributary mouth. This distance was felt to be sufficient to protect against any backwater effects from the main stem. Tributary levees will be an essential part of any main stem levee system, and their costs will be a significant part of the total cost. Table 18 summarizes data on the tributary levees required for the 100-year main stem levee system.

Table 18 - Tributary levee data (for 100-year protection) (1)

Reach	State	Tributary	Average levee height (feet)	Levee length (miles)	First cost
2	MN	Grand Marais	4.1	8.0	$723,000
4	MN	Snake	4.3	7.6	1,289,000
	ND	Forest	2.1	1.7	155,000
5	ND	Park	3.8	1.6	133,000
6	MN	Two Rivers	4.7	3.1	661,000
	ND	Pembina	3.1	5.8	787,000

(1) The Marais River in reaches 2, 3, and 4 on the North Dakota side is within the 100-year main stem levee, and hence a separate tributary levee is not needed. For levees offering less than 100-year protection and thus being closer to the Red River, a separate levee along the Marais River may have to be added.

The estimated cost for agricultural levees is shown by reaches and States in table 19.

Table 19 - First costs for construction of 100-year agricultural levees (1)

Reach	Costs	
	North Dakota	Minnesota
1	$1,303,000	$802,000
2	1,190,000	2,859,000
3	555,000	738,000
4	1,290,000	2,499,000
5	1,219,000	1,920,000
6	5,867,000	6,017,000
Subtotal	11,424,000	14,835,000
Total	$26,259,000	

(1) Includes costs for tributary levees.

Costs for individual construction items are summarized in table 20.

Table 20 - Cost of individual construction items

Item	Unit	Quantity	Unit cost	Total cost
Fill	CY	6,774,300	$1.75	$11,855,000
Topsoil	CY	1,109,500	2.00	2,210,000
Clearing	CY	526,000	5.00	1,052,000
Stripping	CY	1,273,000	1.00	1,273,000
Seed	Acre	137,000	4.00	548,000
Land(1)				1,144,000
Culverts	LF		35.00	3,800,000
with flapgates	Each		6,000.00	
Subtotal				21,882,000
Contingencies (20 percent)				4,377,000
Total				26,259,000

(1) The land cost varies [illegible]/acre in Reach 6 (ND) to $1,600/acre in Reach 1 (MN).

The average annual benefits for 100-year agricultural levee protection are summarized in table 21.

Table 21 - Average annual benefits for 100-year levees

Reach	Benefits		
	Nonurban residential	Other agricultural	Total
Minnesota			
1	$13,600	$20,300	$33,900
2	16,200	439,300	455,500
3	87,700	264,000	351,700
4	60,000	621,700	681,700
5	26,200	314,600	340,800
6	48,300	392,900	441,200
Subtotal	252,000	2,052,800	2,304,800
North Dakota			
1	7,700	21,800	29,500
2	27,700	222,200	249,900
3	14,100	233,200	247,300
4	12,700	213,600	226,300
5	2,000	147,400	149,400
6	6,500	381,600	388,100
Subtotal	70,700	1,219,800	1,290,500
Total	322,700	3,272,600	3,595,300

The average annual damages for "without levee" and 100-year levee conditions were compared to yield the average annual benefits for the 100-year agricultural levees. The benefits, along with the average annual costs and the derived benefit-cost ratios, are shown in table 22.

Table 22 - Benefits, costs, and benefit-cost ratios for 100-year agricultural levees

Reach	Average annual benefits		Average annual costs		Benefit-cost ratio	
	MN	ND	MN	ND	MN	ND
1	$33,000	$29,500	$69,600	$108,500	0.5	0.3
2	455,500	249,900	242,000	101,400	1.9	2.5
3	351,700	247,300	65,400	50,000	5.4	4.9
4	681,700	226,300	212,400	110,900	3.2	2.0
5	340,800	149,400	162,800	106,400	2.1	1.4
6	441,200	388,100	511,300	496,500	0.9	0.8
Total	2,304,800	1,290,500	1,264,000	973,700	1.8	1.3

These numbers are estimates for planning purposes only, intended to give an idea of the relative feasibility of levee construction for the various reaches. This analysis assumes a base condition of no agricultural levees in place. It is also important to note that neither benefits nor costs have been included for the induced damages caused by the extra 0.5-foot depth of flooding in the area between the levees. Although the stage increase caused by this levee system is within the allowable limit set by the States' criteria, it is highly recommended that ring levee protection to the 100-year plus 0.5-foot level be provided for all farmsteads and communities between the levees. There may also be an increase in the duration that the cropland between the levees would be inundated. These costs do not include environmental enhancement measures, nor are the agricultural benefits reduced to account for the option of allowing the land between the levees to revert to natural conditions.

The overall benefit-cost ratio for the entire Grand Forks to border reach is 1.6 (benefits = $3,595,300, costs = $2,237,700). This analysis indicates that 100-year protection built to local standards and using local costs is potentially feasible for a number of reaches along the river. These reaches are essentially the same ones (Reaches 2 through 5) where farmers have already constructed levees offering less than 100-year protection. The use of Federal costs and standards for construction, including 2 feet of freeboard on the agricultural levees, would at least double the costs and would result in an overall benefit-cost ratio less than 1.0.

The question remains whether levees providing a lesser degree of protection and still complying with the criteria would be feasible. Given the large number of variables involved in estimating costs and benefits for various levee systems (e.g., height/setback combinations, tributaries, existing roads and structures, etc.), we have not calculated the economics for other possible systems of agricultural levees. According to our best professional judgment, however, the optimum level of protection to give the maximum benefit-cost ratio would fall in the 10- to 20-year range of protection.

D. ENVIRONMENTAL IMPACTS OF THE 100-YEAR LEVEE ALIGNMENT

Because of the setbacks required to comply with the States' criteria for levee construction, only minor temporary impacts associated with construction could be expected. In most instances, land use is currently agricultural.

Some impacts may be significant in those areas where the levees approach the floodplains of the tributaries. Flanking levees would need to be constructed some distance upstream to protect against flood damages from the backwaters of the Red River. If adequate setbacks are not observed, some riparian habitat could be lost along these tributaries.

The opportunity exists to significantly improve the natural resources in the area between the proposed setbacks. Many of the proposals outlined in the environmental guidelines section would improve wildlife habitat quality and decrease erosion in the main stem area as compared to existing conditions.

E. RECREATION IMPACTS OF THE 100-YEAR LEVEE ALIGNMENT

See Appendix E.

F. CULTURAL RESOURCE IMPACTS OF 100-YEAR LEVEE ALIGNMENT

The cultural resource impacts associated with the 100-year floodplain plan are difficult to determine. Much of this plan involves construction of levees more than one-fourth mile away from the river - a geographic area from which cultural resource data are unavailable. The primary impacts to sites are expected where portions of the levee will be located within one-fourth mile of the river. This conclusion, however, is based on Michlovic's survey results south of the study area and does not necessarily reflect conditions within the study area. The area beyond this distance has not been investigated. Thus, impacts for that portion of the levee more than one-fourth mile from the river cannot be determined from existing data. In addition, implementation of this plan could affect historic standing structures by raising the flood stage one-half foot.

The fill sources for construction of the levees for the 100-year floodplain alignment could also affect cultural resources. These impacts could result from either the level scraping of fields for material or from excavation of borrow pits for fill.

All probable impacts are based on limited information. Cultural resource surveys have not been conducted in the area, and, until the exact number, type, and location of sites are known, a detailed determination of the impacts on cultural resources is impossible.

III. GUIDELINES FOR AGRICULTURAL LEVEE CONSTRUCTION

Previous sections of this report have detailed some of the engineering problems that have accompanied the construction of private agricultural levees along the Red River of the North. The institutional problems associated with these levees have been well documented by the local press in the Red River Valley. In many ways, these institutional problems may be more insurmountable than the technical problems. Yet the fact remains that the agricultural levees that have been constructed have been partly successful, and the criteria allow for modification of existing levees and construction of new levees. We would, therefore, like to affirm some general guidelines to minimize the adverse impacts of any future agricultural levee construction.

A. HYDRAULIC GUIDELINES

The States' criteria set the limit for the maximum permissible stage increase that may be caused by the levees. Because the criteria specify the 0.5-foot limit only in reference to the 100-year flood, a certain latitude in levee location and height is allowed. To generalize, the higher the levee, the farther back it must be from the river to comply with the criteria.

Hydraulic analysis of possible levee height-setback combinations was completed for a short reach of the Red River between river miles 239.44 and 245.46 (cross sections 4600 through 4900). The topography, flow conditions, cross section spacing, and floodplain characteristics are reasonably typical and representative of the entire reach.

This simplified analysis was based on an extension of previous methods used to analyze levee overtopping situations. The following assumptions were made:

1. Flow could pass over levees and between cross sections with a head loss of 0.1 foot.
2. Friction effects of the levees are negligible.
3. Flow is uniform.
4. Flow velocities are perpendicular to the tops of levees.

5. A linear water surface profile exists between cross sections.

6. Flow distribution from the HEC-2 model is reasonable and valid.

7. Levee heights would be based on an average elevation in the overbank.

To meet the States' criteria, a floodway with encroachments which limit the stage increase to 0.4 foot was computed for a range of discharges less than the 1-percent chance flood. The one-half foot stage increase is based on 0.4 foot resulting from encroachment plus 0.1 foot resulting from the head loss produced by the levees when overtopped. A discharge-setback curve for this condition is shown in figure 18.

In the reach analyzed, approximately 26,760 lineal feet of agricultural levee exist. Inspection of aerial photographs indicated that the levee alignment used in this reach was typical and could reasonably be expected to be used elsewhere. A unit-discharge per foot of levee versus total discharge was developed using information computed in the HEC-2 model. The distance the top of levee would have to be below the design water surface elevation was computed using the energy equation for flow in the lateral direction and making simplifying assumptions. These computations were done for a range of discharges and average ground elevations in the overbanks for each cross section. The results were compared and averaged and a discharge versus levee height curve developed (figure 19).

By combining the discharge-levee height and discharge-setback curves, a setback versus levee height curve was derived for the conditions stated (figure 20).

These curves for the "typical reach" are meant only to illustrate possible levee height-setback combinations. Analysis of different reaches would produce different results, but overall similarities could reasonably be expected.

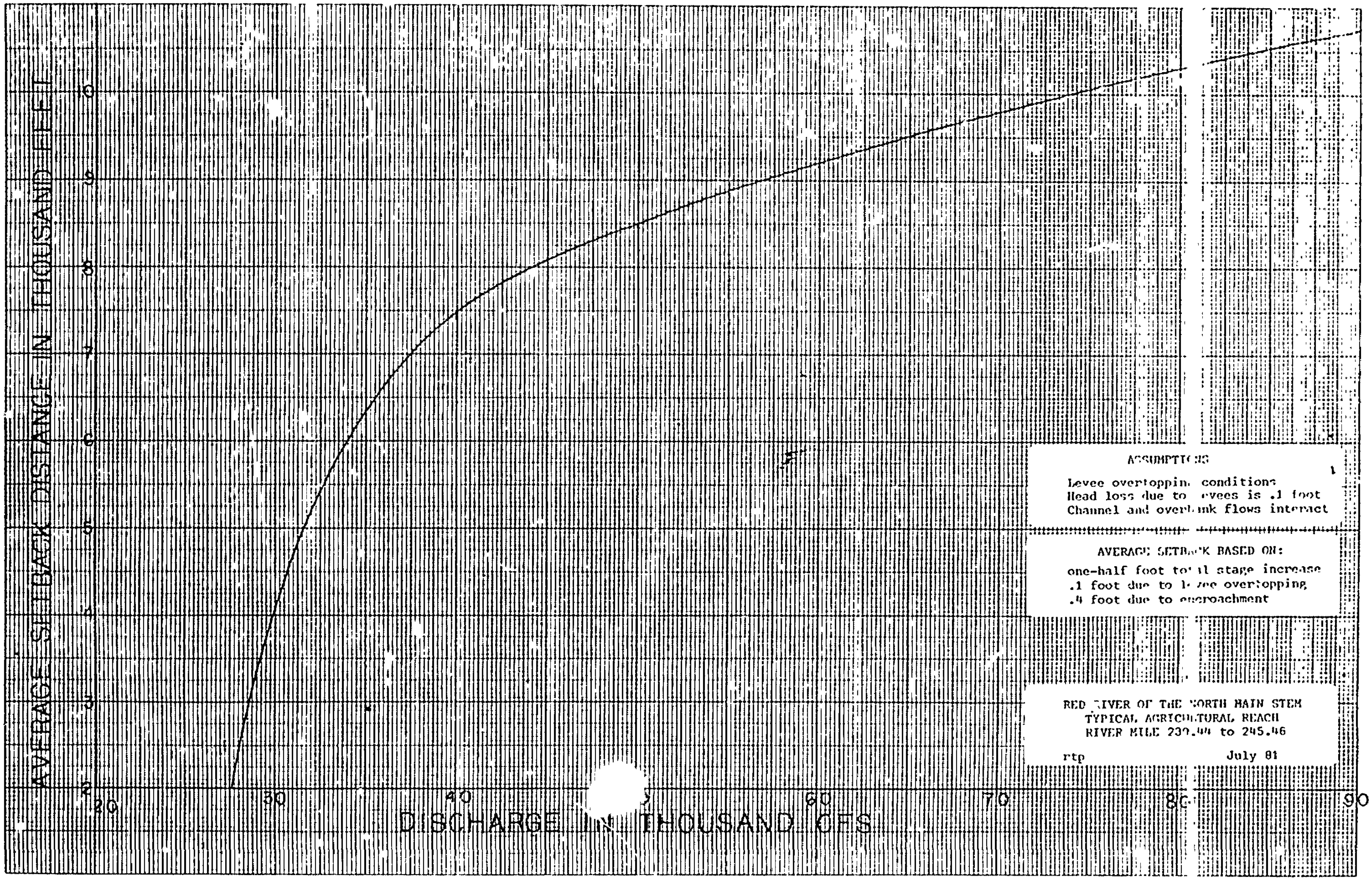


Figure 18 - Discharge-setback curve

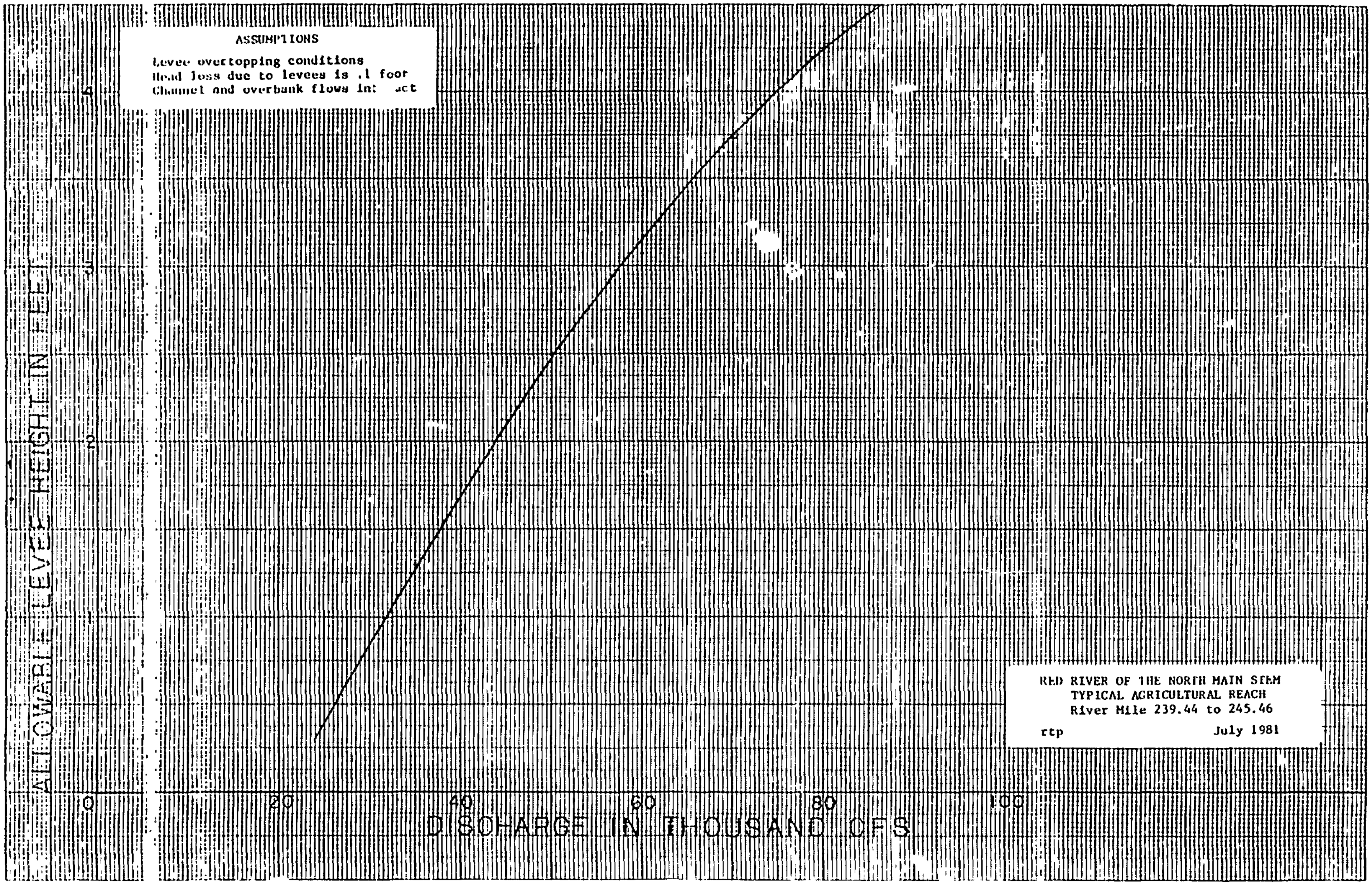


Figure 19 - Discharge vs. levee height curve

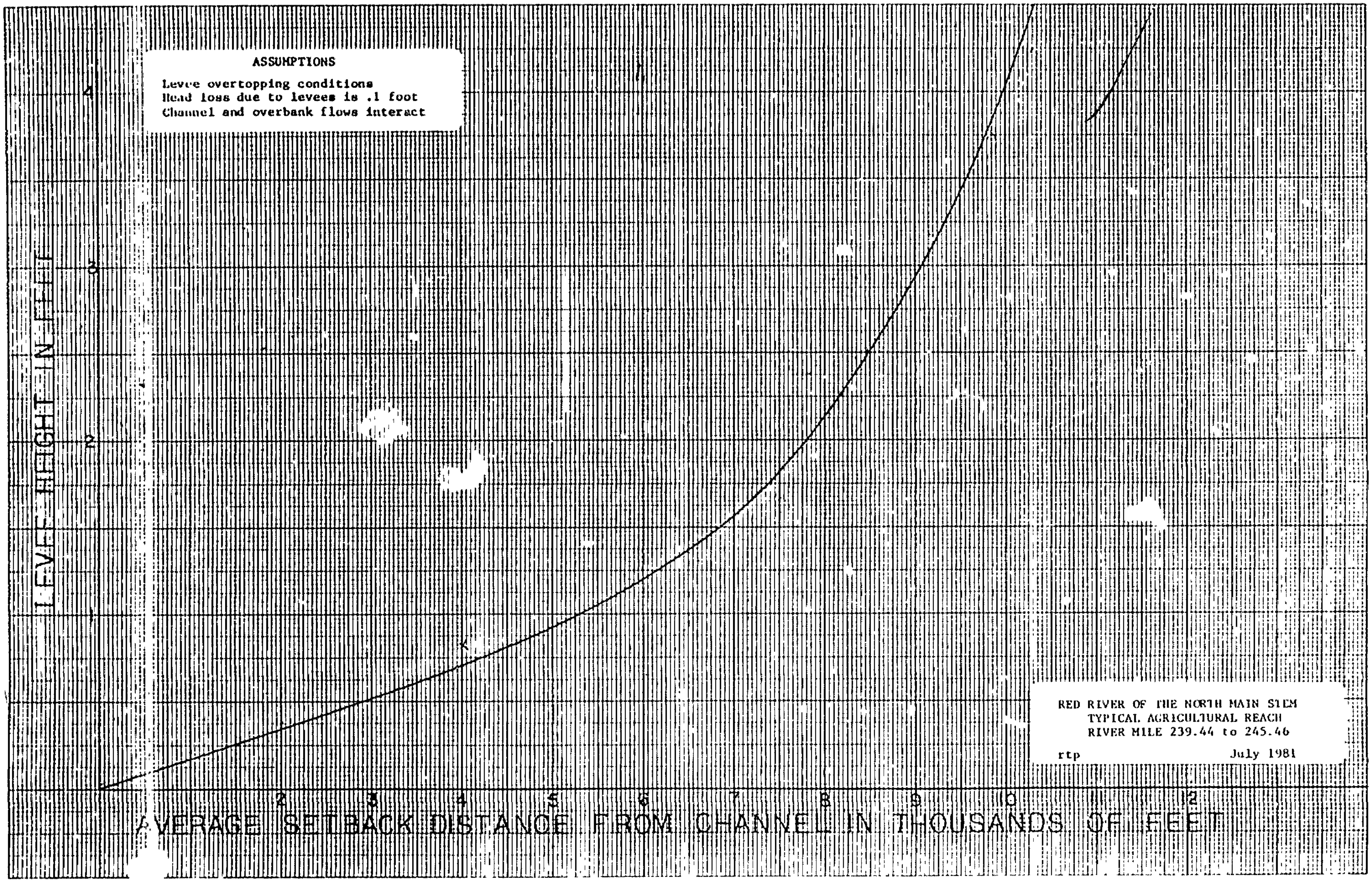


Figure 20 - Setback vs. levee height curve

B. FOUNDATION GUIDELINES

1. Regional History

Within this century, many foundation failures have occurred along the Red River. The most famous are the Transcona Grain Elevator in Manitoba and the Great Northern Railway bridge at Grand Forks. Other serious problems occurred during or relatively soon after construction of all types of structures including buildings, roadways, and levees. With secondary banks (where the lake plain meets the river cut) typically located about 400 feet from the river's edge, the temptation to extend lake plain elevation riverward has been irresistible. A good example of this practice can be seen in Grand Forks and East Grand Forks where eight slides have occurred where fill was placed near or over the secondary bank.

The Red River Valley is the lake bed of glacial Lake Agassiz, which covered the area during the retreat of the last glacier from the region. The river has cut into the lake plain and formed a meander belt without a well-developed floodplain. Slopes from the lake plain to the river's edge are undeveloped and covered with a dense growth of brush and timber. These banks are heavily scarred with old slides and sloughs.

2. General Geology

As the last glacier receded north, it formed a barrier to northward drainage. This barrier created a large lake, Lake Agassiz, in the present area of the Red River Valley. Rivers, swollen with water from the melting glaciers, carried large quantities of sediment into the lake. The coarse sediments were deposited as deltas and worked into beach lines near shore. The fine silts and clays were carried out into the lake where they settled and formed deposits up to 150 feet thick. As the ice barrier melted, the northward drainage was reestablished, and sediments were exposed to weathering and erosion. The Red River and tributaries were established and cut steep-sided meandering channels into the nearly level, soft lake sediments. As a result of the recent geologic development in the basin, the lake sediments are characterized by poor consolidation and high natural water content.

3. Geologic Column

The materials in the area are easily recognized and correlated with materials found elsewhere in the Lake Agassiz basin. Four major soil types are present within the influence of existing and proposed levees: fluvial (river deposited) sediments, two types of lacustrine (lake deposited) sediments, and sediments deposited by glacial ice.

The glacial sediments underlie the lacustrine clays throughout the region and represent the original bottom of Lake Agassiz before filling began. These sediments are characteristically more competent than the other three soil units. No evidence of failures exists within these materials.

The lower lacustrine sediments, or dark gray clays, are present throughout the area. This soil type is extremely weak and is primarily responsible for the region's notoriously poor foundation characteristics. The unit is thicker outside than within the meander belt where the river has partially eroded it.

The upper lacustrine sediments (laminated silty clays) are not as thick as the lower lacustrine sediments. These laminated silty clays may be found at or near the surface outside the meander belt or may be buried by thick fluvial deposits within the meander belt. This soil type is only slightly stronger than the dark gray clays.

The fluvial sediments (river deposits) are the youngest in the region and are restricted in significant distribution to the meander belts of rivers. Fluvial sediments consist of discontinuously stratified and mixed deposits of silt and clay. These deposits are the strongest within the zone of influence for sliding.

4. Mechanics of Bank Failure

Every slope is constantly subject to natural forces tending to smooth it out or flatten it. Equilibrium may be disturbed by an increase in forces contributing to sliding (additional weight on top of the bank) or decrease in forces resisting sliding (erosion of the primary bank or river bottom and very low river elevation). Landslides of the type in question are usually deep-seated. When the failing earth mass breaks away from the lake plain

mass, it moves as a section approximating a segment of circular arc (called a rotational landslide; see figure 21. The ability of a slope to resist movement also depends on the strength or ability of a soil to resist shearing. See figure 22 for an illustration of the importance of soil positioning. In the "best case," most of the potential failure surface is within fluvial sediments which have a relatively high shear strength. In the "worst case," the potential failure surface is wholly within the weaker lacustrine sediments and the lower lacustrine deposit is very thick. The worst case is most likely to occur on the outside of a river bend at the edge of the meander belt. The best case is most likely to occur on the inside of a bend within the meander belt.

Tension cracks run parallel to the secondary bank and cup in toward the river at both ends. They are a warning that failure is imminent. Actual bank failure is usually brittle with a rapid displacement of from a few inches to a few feet. Initial displacement is often followed by years of slow, intermittent movement. It is a characteristic of clays in the valley, and many other clays, to weaken with disturbance by shearing or sliding. That is, even though sliding has occurred, thereby reducing driving forces by lowering the bank and raising the river bottom, soils along the plane of failure are weaker than before sliding occurred. Any added loading where sliding has previously occurred could trigger more rapid movement or extend the time and total displacement of slow movement.

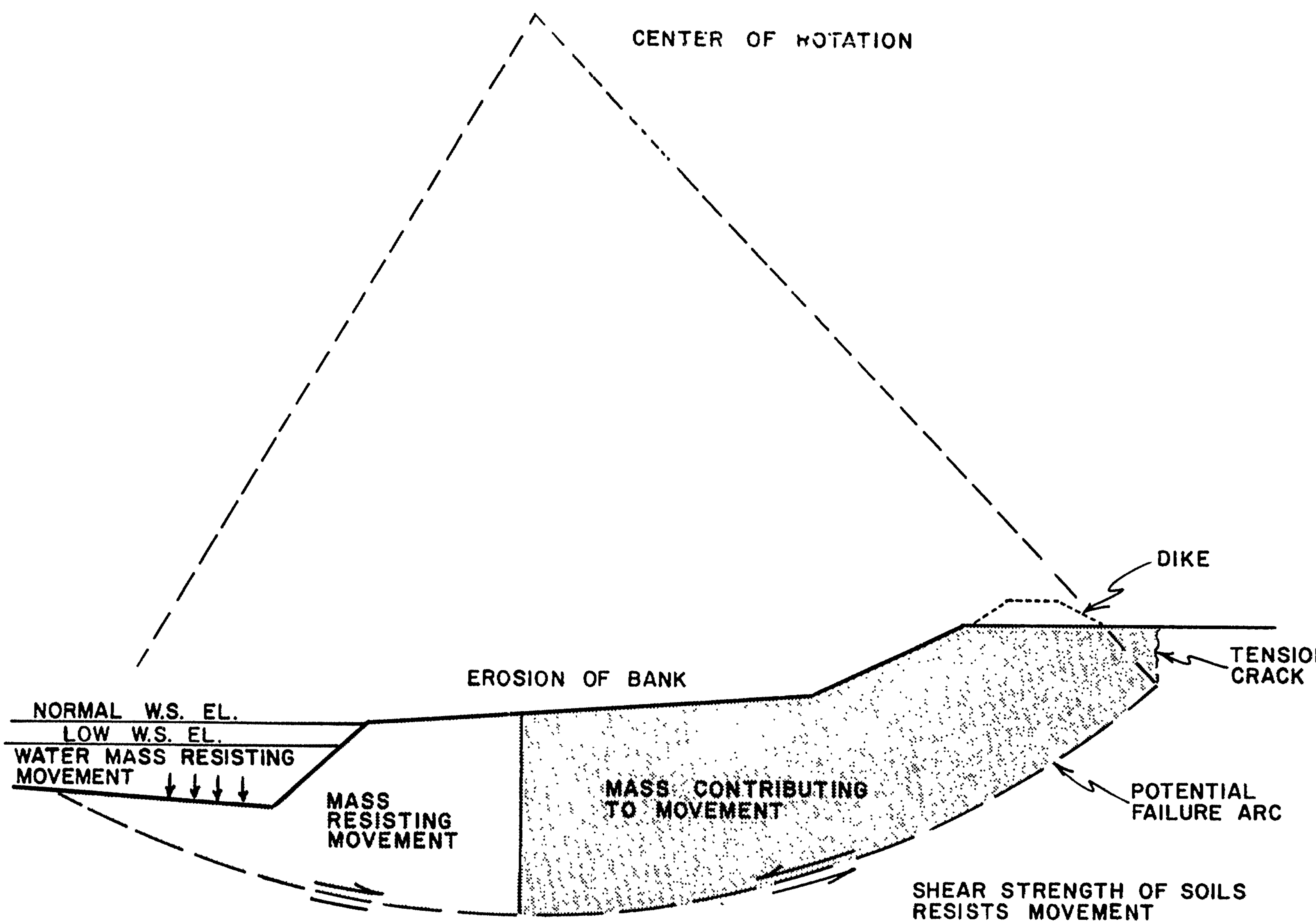


Figure 21 - **ROTATIONAL LANDSLIDE**

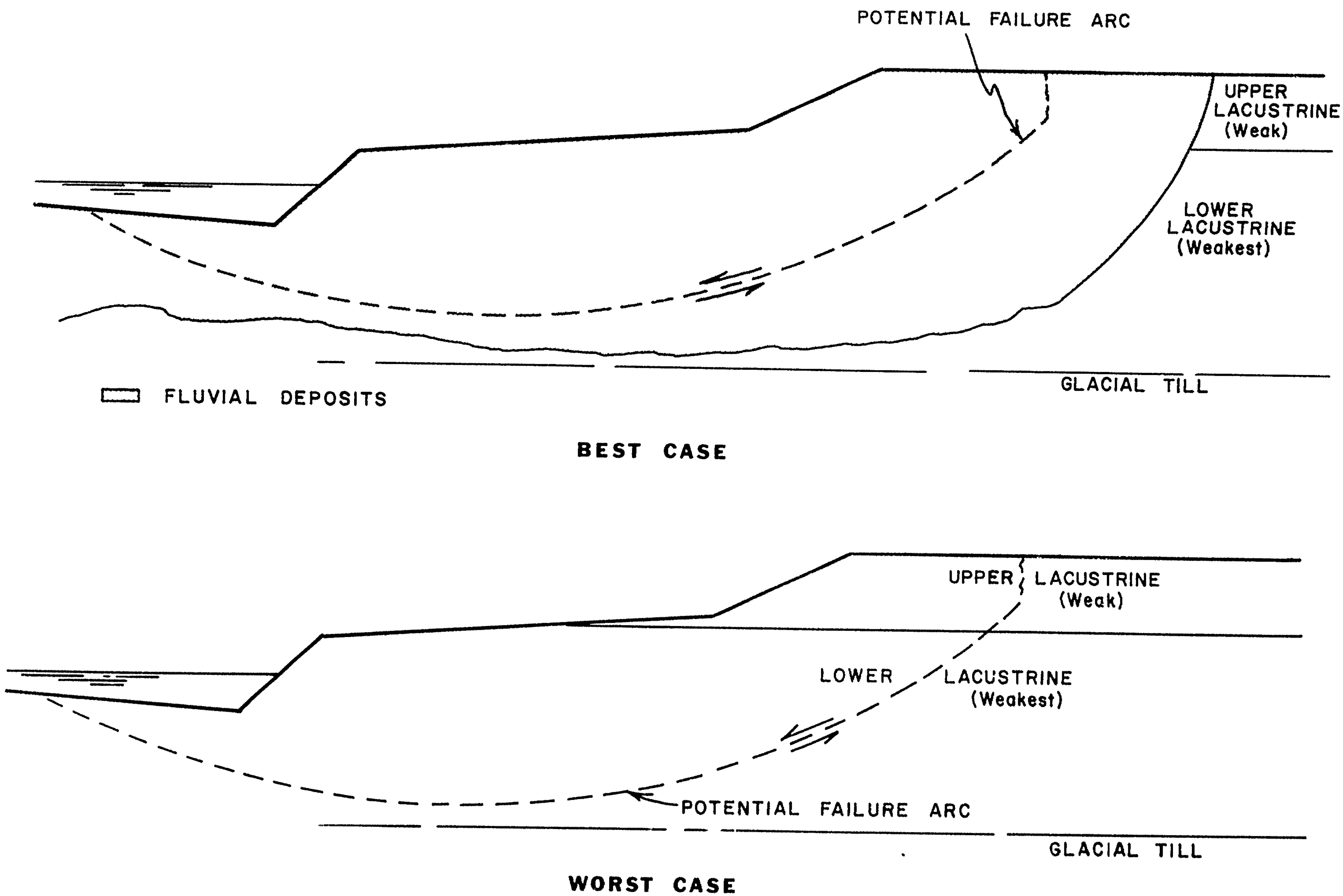


Figure 22 - **POTENTIAL FAILURE SURFACES**

When displacement occurs, the bank-full section changes shape but the flow area is preserved because the falling secondary bank increases bank-full channel area by an amount equivalent to that lost by the heaving river bottom. Because of this phenomenon, an illusion is created that the hydraulic capacity of the river is unchanged. In fact, the center of the channel where area is lost by sliding is hydraulically much more efficient than the upper bank where area is gained by sliding. The net result is reduced capacity of the river to carry flows and higher water surface elevations for a given quantity of flow. This is one reason it is important to minimize sliding.

5. Condition of Existing Levees

A great deal of variability occurs in the existing levees mainly as a result of construction techniques, with quality and existing conditions generally best near Oslo. Top widths vary from less than 5 feet to more than 20 feet where levees are used as driveways or are built-up county roads. Side slopes vary from approximately 1V on 1H to 1V on 4H. Generally levees are not mowed and are covered with tall grasses and/or weeds.

Field inspection of stability conditions in summer 1980 was extremely difficult because of the heavily vegetated nature of sides and tops of most levees and limited access to levees. Except where levee tops had been driven over, deterring vegetation, cracking had to be felt for more than looked for. Basically, two types of cracks were observed: randomly oriented cracks up to 2 inches wide caused by shrinkage and cracks running parallel to the levee up to 4 inches wide. Shrinkage cracks were unusually large because of dry weather and could be observed on the permanent project at Oslo for reference. The generally wider parallel cracking was not observed everywhere and, more often than not, was caused by localized sloughing (shallow face slippage). Probably, more parallel cracking exists than was observed

because of difficulty with observations. Considerable sloughing was observed, especially on the North Dakota side of the river. No major vertical displacements resulting from riverbank sliding were observed; but, because of the limited number of areas visited and the heavy vegetation cover, many could have been missed. Major sliding may be occurring riverward of the levee without signs of stress within the levee. Where this is observed, the levee should be moved landward.

Several practices that were evident should be addressed. Farmers should be discouraged from plowing and planting right up to the landward toe of levees; an exception to this will be explained later. Evidence indicating encroachment by farm equipment on levees was observed. This tends to form a vertical face at the toe and in some cases causes the levee face to slough. New levees and/or portions of old levees should be provided with a well graded and gravel surface or planted with grass and mowed at regular intervals so that vegetation does not grow higher than 6 inches. This is to aid inspection and observation during emergency periods and discourage rodent problems. Trees also create possibly turbulent flow problems and interfere with proper maintenance. If trees are in place, the practice of filling around them should be discouraged because it may kill the trees and does not result in a permanently sound structure. Obstacles to flow such as concrete rubble and discarded refrigerators should be kept off the levees because they may create an erosion problem and prevent placement of erosion protection if needed under high-water conditions. Where levees are known to contain significant quantities of substandard fill materials such as wood or highly organic soil, they should be cut out and rebuilt. A positive feature of most of the levees is that they have generally been built entirely landward of the secondary bank on the lake plain and with locally borrowed material. This contrasts sharply with urban areas where, generally, because the structures are close to the river, additional fill from outside areas must be placed riverward of the lake plain.

6. New Levee Standards

Levees should be built with a 10-foot minimum top width and have slopes no steeper than 1V on 3H. It is generally best to borrow material for levees riverward of proposed placement from a stability standpoint. Where stability is suspect, top widths may be narrowed, slopes steepened, and all material for construction borrowed riverward of the levee. This compromise in integrity is justifiable only where earth movements are especially threatening. Under no circumstances should fill be placed on a sliding crack or riverward of a crack if movement has occurred or is occurring. Setbacks from the riverbank will be necessary. The farther landward a levee can be set back, the less the possibility that construction will cause a sliding type failure. No general standards for areas of questionable stability are possible.

Culverts and conduits extending through levees should receive special care in placing and compacting fill. The landward third of pipes should be encased in an 18-inch blanket of clean sand or gravel with an exit for seepage provided. Cutoff or seepage fins should not be used.

All borrow areas, ditches, and levee slopes should be seeded with grass and/or cared for as needed to establish proper cover. Levee tops may be graveled and widened where safe for other uses or seeded.

7. Special Conditions

It has been assumed that all levees will be built on a clay foundation. However, sands and silts may be encountered. In these cases, professional help should be sought because the design standards presented are not adequate. This condition is most likely to occur in the sand-gravel beach ridges along the edge of the old lake plain.

If any sand or gravel from past flood fights or any other source is used in levee construction, it must be placed landward of a riverward clay face. A sand or gravel layer through the entire levee section must be avoided.

Where low levees cross cultivated fields, very flat slopes and wide top widths are preferred. These levees can be cultivated but special care may be required so that levee profile elevations are maintained. By cultivating, weed, debris, and rodent problems are eliminated. The flat riverward slope compensates for the scour problems caused by wave action and currents.

Where old river channels are crossed, the levees will probably be high and the foundation soils will probably be fluvial. This combination may result in significant settlement. It is recommended that these levees be resurveyed on the first and fifth years after construction and restored to original grade if settlement occurs.

8. Construction and Maintenance Procedures

Soils for levee construction should be placed in lifts not exceeding 12 inches and thoroughly compacted by careful routing of construction equipment. Generally, special equipment for compaction is not needed. The surface of each lift should be loosened if it becomes too smooth to permit proper bonding of the next lift. Soil for placement should be moist enough to deform without crumbling and dry enough so that excessive shrinkage will not occur once in place. Tops and sides of levees will be graded to provide smooth, even surfaces. Before fill is placed, the foundation will be cleared and stripped of vegetation. Grass cover will be established and mowed as needed to limit growth to 6 inches.

9. Summary

To build a levee properly requires greater initial investment that that made in those levees already built. To maintain a levee properly requires regular effort. Although poorly built levees have performed their function, many have failed. In the long run, looking at the reduced rate of deterioration and likelihood of failure inherent in a properly built levee and considering the consequences of failure, the greater effort to do it right the first time is worth it.

C. ENVIRONMENTAL GUIDELINES

The construction of levees to reduce flood damages in agricultural areas has had adverse impacts on natural resources. Floodplains have been cleared and converted to cropland resulting in the direct loss of wildlife habitat and increased erosion. However, opportunities exist to improve wildlife habitat and reduce erosion in the main stem area in conjunction with levee construction. By considering levee alignment, land use between the levee and the river, and construction techniques, environmental quality can be greatly enhanced with little additional cost.

1. Alignment

Levees should be as far as possible from the riverbanks. A minimum setback of at least 500 feet would be most advantageous. This setback would provide a floodway of at least 1,000 feet and would help minimize erosion problems.

More important, setbacks should be outside the existing tree line if at all possible. Riparian woods in the main stem area are a valuable resource. They provide areas for recreation and wildlife habitat and help to stabilize the soil near the river, thereby reducing riverbank slumping.

2. Land Use Between the Levees and the River

In some areas, it may be more advantageous to change farming practices in the area between the river and the levee. These areas will be subjected repeatedly to flood damages and, as a result, will be more susceptible to erosion during floods.

One method of reducing erosion would be to institute conservation tillage practices, such as no fall plowing or no tillage. By not plowing in the fall, the field residue would help reduce erosion in the spring. No-till farming would be even more effective in achieving this effect. However, minimum tillage often requires the increased use of pesticides to maintain acceptable yields and could contribute to water quality degradation during periods of high runoff.

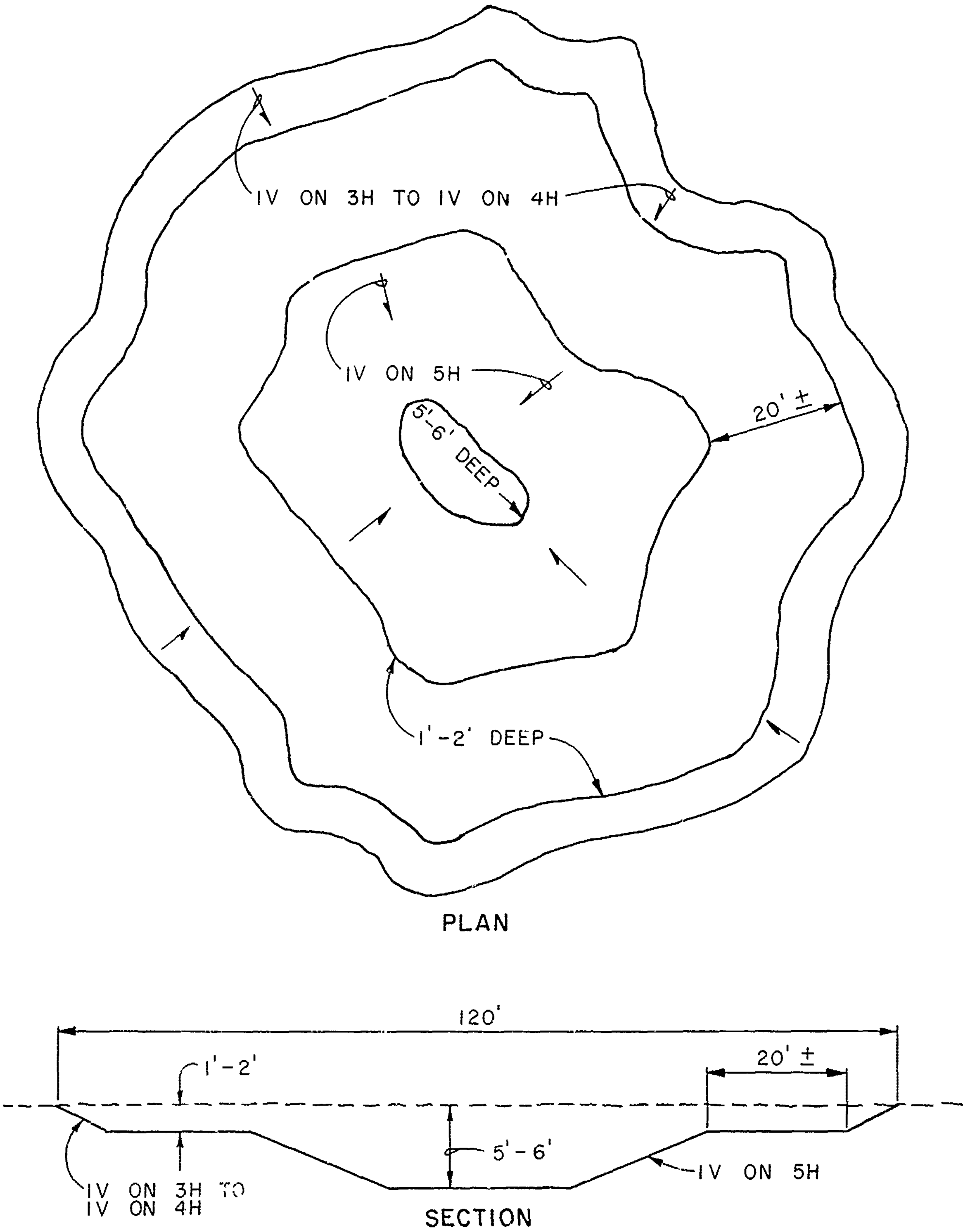
Another alternative would be to discontinue any row crop production in the setback areas and use these areas as pasture or for hay production. If these areas are not overgrazed, establishment of a fairly constant ground cover would help reduce erosion.

In areas where levee setbacks are 500 feet or less, it may be desirable to allow natural floodplain vegetation to become reestablished. A more continuous wooded corridor would develop, promoting soil stability and enhancing wildlife and recreation potential along the river. This alternative land use would be most beneficial in locations adjacent to extensively wooded areas.

3. Levee Construction

Depending on the source of fill for levee construction, there are opportunities in some areas for the development of wetlands. If fill material is obtained from a borrow area, it could be excavated in such a manner as to create a wetland. Locating a borrow area on the riverward side of the levee may be feasible in some circumstances, because the setback area may not be suitable for cultivation as a result of susceptibility to flood damages. These wetland developments would be replenished during the spring and would provide valuable habitat for wildlife using the river corridor.

An example of how a borrow area could be excavated for wetland development is shown in figure 23. The pond characteristics shown provide a good mix of shallow areas for the establishment of marsh vegetation and open water. The areas should be a minimum of a one-quarter acre in size with an irregular shoreline. Generally, side slopes should not be steeper than 3 on 1 to minimize the possibility of slumping after excavation is completed. Some permanent seeding of locally adopted grass-legume mixtures should be established around the site to help provide wildlife cover. If the area surrounding the excavation site is to be pastured, the potholes should be fenced to maintain an adequate ground cover. An area of 25 to 40 feet beyond the waterline should be enclosed.



DESIGN FOR BORROW AREA EXCAVATION
TO CREATE A WETLAND AREA

Fig.ıre 23.

D. RECREATION GUIDELINES

See Appendix E.

E. CULTURAL RESOURCE GUIDELINES

Before implementation of any proposed plans for the construction or maintenance of any levees along the Red River, a cultural resource survey is recommended in the area of proposed environmental impact, including any borrow areas, to identify any unknown cultural resources that could be damaged or destroyed by construction. If the proposed undertaking requires Federal assistance, including any Federal permit, license, or approval, the surveys would be mandatory (required by the National Historic Preservation Act of 1966). In addition, the State Historic Preservation Officers and State Archaeologists in each State should be contacted before implementation of any proposed plan to determine if any State cultural resource laws or regulations apply.

F. PERMIT REQUIREMENTS

Permits are required to construct, relocate, rebuild, or alter any agricultural levees to ensure compliance with the established joint criteria. Depending on the location of the dike, applications should be submitted to the Minnesota Department of Natural Resources or North Dakota State Water Commission. Forms and instructions can be obtained from the respective State offices.

Although primary permitting authority resides with these State agencies, approval from other sources may be necessary. County water management or watershed offices should be contacted to see if there are any local restrictions. Also, Federal regulations may require permits through the Corps of Engineers.

The Corps has two principal sources of permit authority: Section 10 of the River and Harbor Act of 1899, which regulates all work in navigable waters up to the ordinary high-water mark, and Section 404 of the Clean Water Act, which regulates the discharge of dredged or fill material into waters of the United States. Section 10 generally does not apply to

agricultural levees on the Red River because the levees are constructed above the ordinary high-water mark. Section 404 does apply since wetlands, intermittent streams, and prairie potholes are all considered waters under Section 404 jurisdiction. The term "wetland" covers a broad range of vegetation and saturated soil conditions; therefore, care should be taken to determine if, in fact, any wetlands are affected before any levee construction or alteration is begun.

In summary, before construction or modification of any agricultural levee, an approved permit must be obtained from the proper State agency. Typically the States should be able to advise an owner if further permits are required from other local, State, or Federal offices. If there is any question or doubt whether further permits are needed, the landowner should contact the local watershed offices and the Corps of Engineers in St. Paul. Failure to acquire all of the proper permits could result in a request for removal of the structure or other legal action.

APPENDIX A

CROSS SECTIONS

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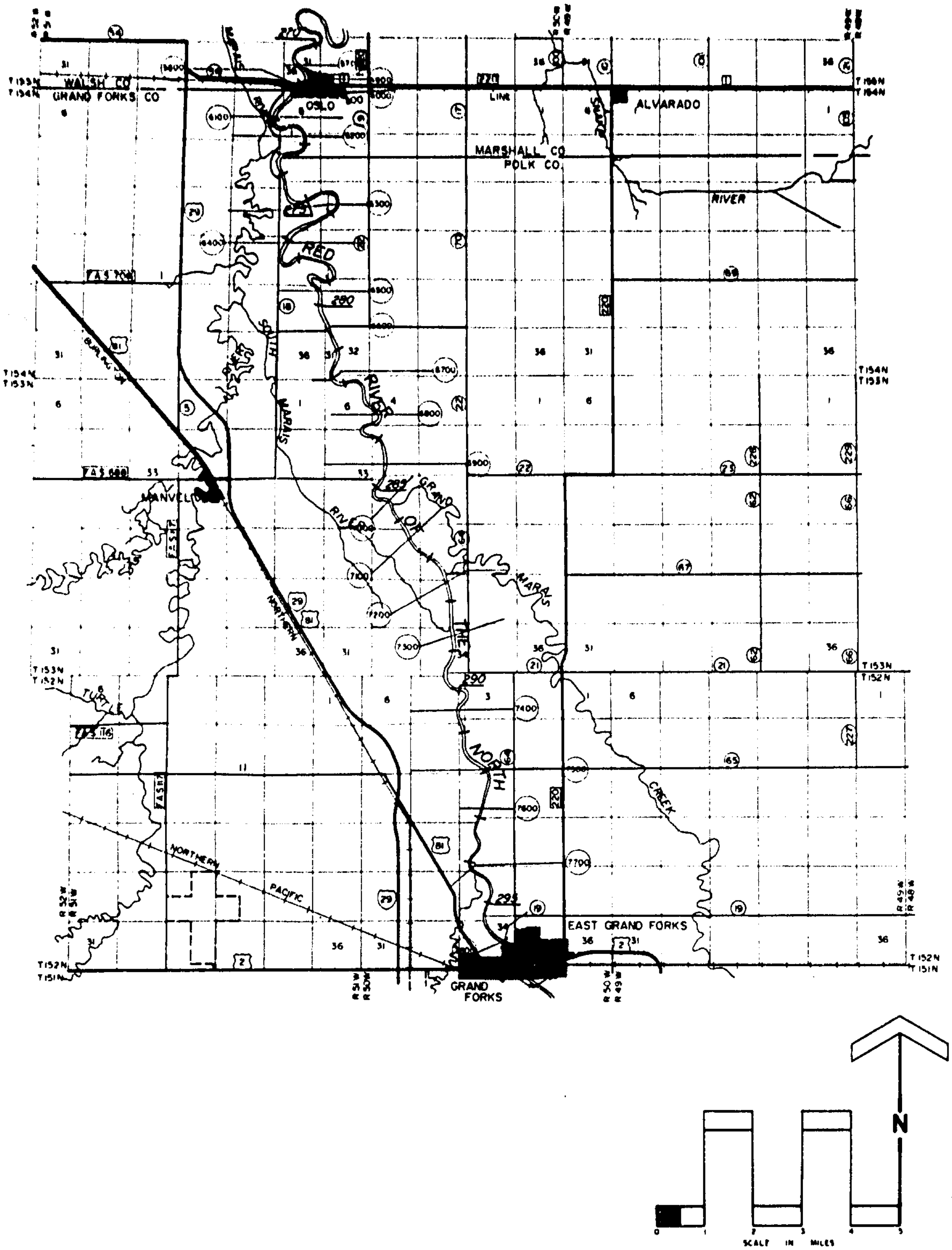
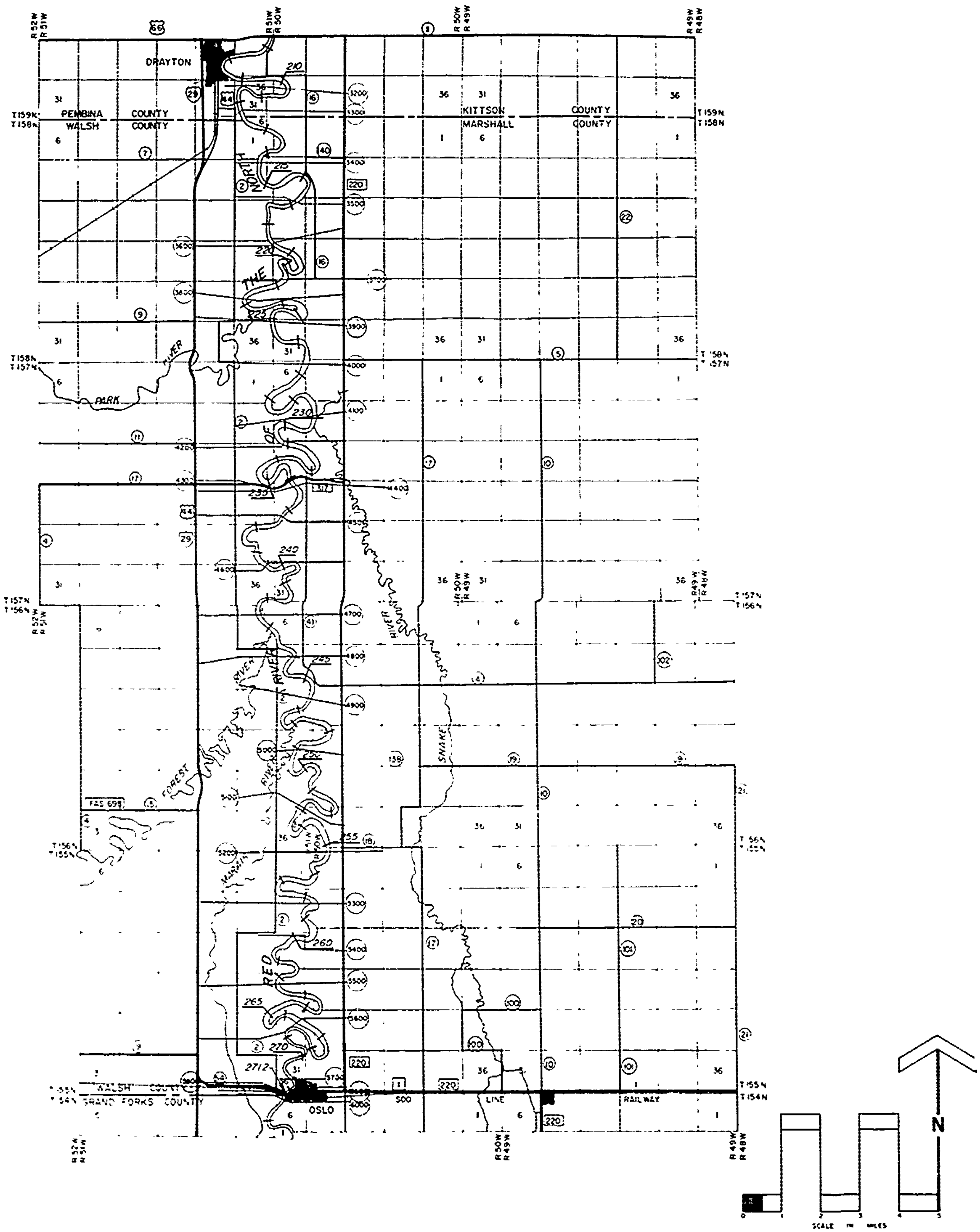


RED RIVER MAIN STEM
REACH 1 - REACH 2
RIVER MILE 271 - RIVER MILE 296
OSLO - GRAND FORKS
1981



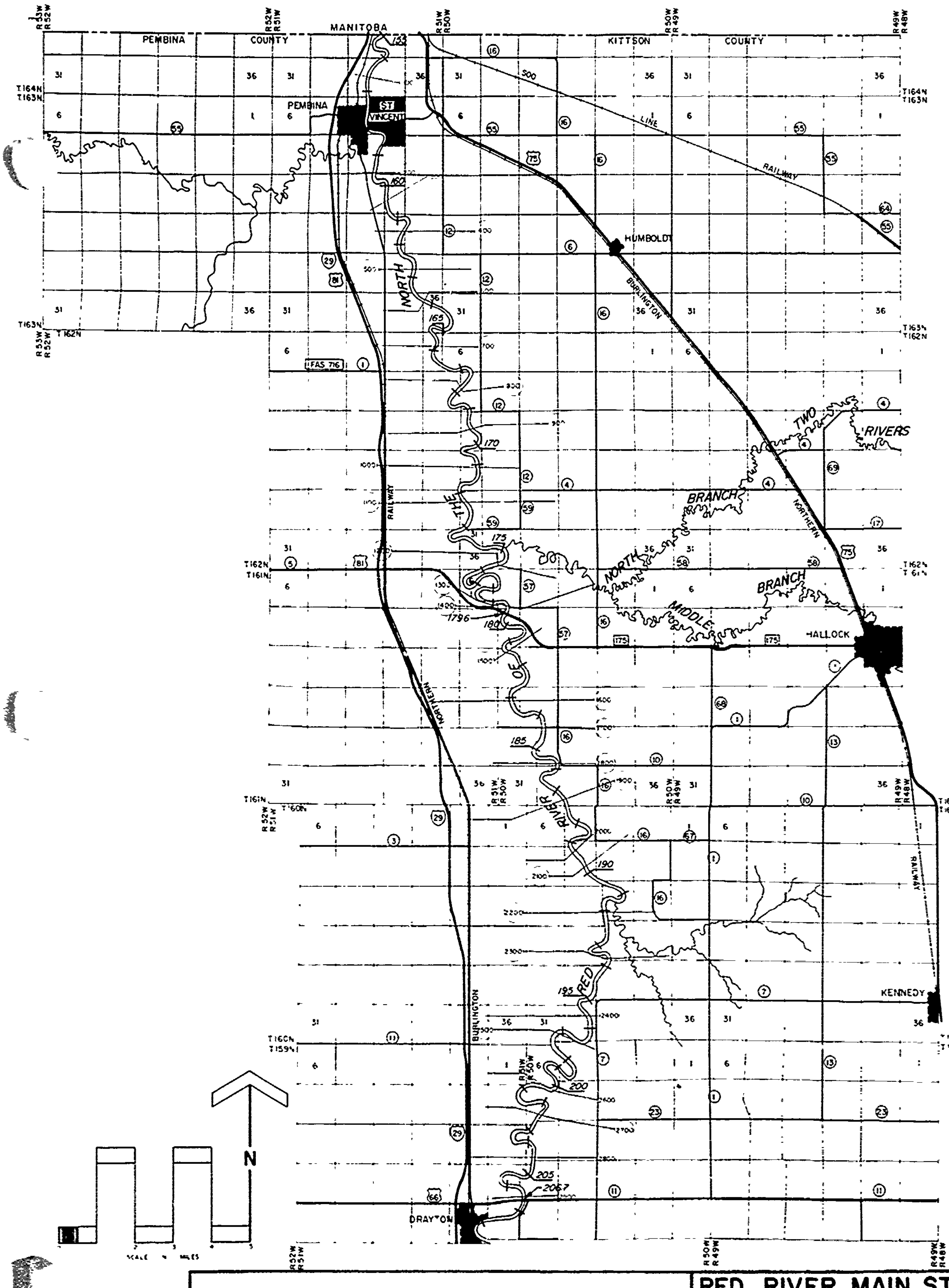
RED RIVER MAIN STEM

REACH 3 - REACH 5

RIVER MILE 206 - RIVER MILE 271

DRAYTON - OSLO

1981



RED RIVER MAIN STEM

REACH 6

RIVER MILE 155 – RIVER MILE 206

INTERNATIONAL BORDER – DRAYTON

1981

TECHNICAL APPENDIX
HYDRAULICS
DECEMBER 1980

TABLE 8

TABULATION OF CROSS-SECTION GEOMETRIC DATA AND RIVER MILEAGE FOR THE RED RIVER OF THE NORTH MAIN STEM FROM EMERSON TO GRAND FORKS, ND.

CROSS SECTION NUMBER	RIVER MILE	CHANNEL LENGTH (FEET)	THALWEG ELEV	LEFT BANK ELEV	LEFT BANK STA	RIGHT BANK ELEV	RIGHT BANK STA	CHANNEL TOPWID (FEET)	SECTION TOPWID-NATURAL
0	154.30	0.0	736.10	775.00	50000.0	775.00	50375.0	375.0	11365.0
.10	154.49	1000.0	736.00	775.00	50000.0	775.00	50570.0	570.0	11000.0
.20	154.58	475.0	736.50	793.00	50000.0	794.00	50500.0	500.0	25000.0
.21	154.59	50.0	736.50	793.00	50000.0	794.00	50500.0	500.0	25000.0
.30	154.63	225.0	739.00	775.00	50000.0	775.00	50530.0	530.0	20000.0
.40	154.72	450.0	740.00	794.50	50000.0	793.90	50736.0	736.0	25700.0
.50	154.73	50.0	740.00	794.50	50000.0	793.00	50736.0	736.0	25700.0
.51	154.74	50.0	740.00	794.50	50000.0	793.00	50736.0	736.0	25700.0
.52	154.75	50.0	741.00	775.00	50000.0	775.00	50460.0	460.0	11000.0
.60	154.99	1300.0	738.00	775.00	50000.0	775.00	50532.0	532.0	12000.0
100	156.78	9450.0	738.21	771.70	50000.0	779.81	50420.0	420.0	12700.0
10	157.16	2000.0	739.80	775.00	50000.0	775.90	50439.0	439.0	13300.0
9	157.49	1750.0	739.40	775.00	50000.0	775.80	50391.0	391.0	13950.0
8	157.64	800.0	739.60	762.00	50000.0	763.40	50364.0	364.0	14600.0
7	157.79	800.0	741.60	763.10	50000.0	765.50	50352.0	352.0	13800.0
6	157.97	950.0	740.10	763.10	50000.0	768.70	50385.0	385.0	14950.0
5.10	158.03	300.0	740.10	765.00	50000.0	777.40	50521.0	521.0	13400.0
5	158.03	1.0	740.10	765.00	50000.0	777.40	50521.0	521.0	13400.0
4.10	158.11	400.0	736.00	794.10	50000.0	797.40	50768.0	768.0	16000.0
4.20	158.11	22.0	736.00	794.10	50000.0	797.40	50768.0	768.0	16000.0
4	158.19	400.0	739.10	769.10	50000.0	780.00	50500.0	500.0	15600.0
3	158.36	900.0	738.00	760.00	50000.0	775.00	50500.0	500.0	15900.0
2	158.60	1300.0	737.20	775.00	50000.0	775.00	50500.0	500.0	14700.0
1	159.17	3000.0	737.92	767.02	50000.0	766.32	50350.0	350.0	14200.0
200	159.46	1530.0	739.89	781.99	50000.0	783.29	50730.0	730.0	15800.0
300	160.46	5290.0	739.96	786.36	50000.0	779.99	50670.0	670.0	25580.0
400	161.69	6492.0	734.20	786.26	50000.0	779.77	50830.0	830.0	27500.0
500	162.87	6202.0	735.60	783.59	50000.0	779.35	50850.0	850.0	23700.0
600	163.71	4457.0	743.06	775.01	50000.0	780.35	50615.0	615.0	22000.0
700	165.99	12016.0	742.63	781.95	50000.0	777.93	50662.0	662.0	20000.0
800	167.73	9206.0	741.00	785.10	50000.0	779.10	50760.0	760.0	37070.0
900	169.49	9303.0	741.30	777.90	50000.0	787.60	50690.0	690.0	23850.0
1000	171.05	8237.0	741.70	782.80	50000.0	784.40	51070.0	1070.0	34500.0
1100	172.34	6783.0	739.70	780.60	50000.0	785.90	50800.0	800.0	42270.0
1200	175.46	16474.0	746.10	783.40	50000.0	776.00	50431.0	431.0	39390.0
1300	179.44	21028.0	742.29	781.20	50000.0	778.89	50755.0	755.0	38590.0
1310	179.54	520.0	741.30	800.60	50000.0	798.60	51310.0	1310.0	42800.0
1320	179.55	40.0	741.30	800.60	50000.0	798.60	51310.0	1310.0	42800.0
1400	179.63	420.0	739.74	784.13	50000.0	776.34	50540.0	540.0	41400.0
1500	181.63	10606.0	738.35	782.49	50000.0	788.04	50923.0	923.0	42000.0
1600	183.22	8348.0	748.00	788.20	50000.0	782.90	50875.0	875.0	39345.0
1700	184.48	6678.0	745.99	786.52	50000.0	783.39	50545.0	545.0	38300.0
1800	186.08	8446.0	739.84	779.82	50000.0	786.24	50540.0	540.0	34500.0

TABLE 8

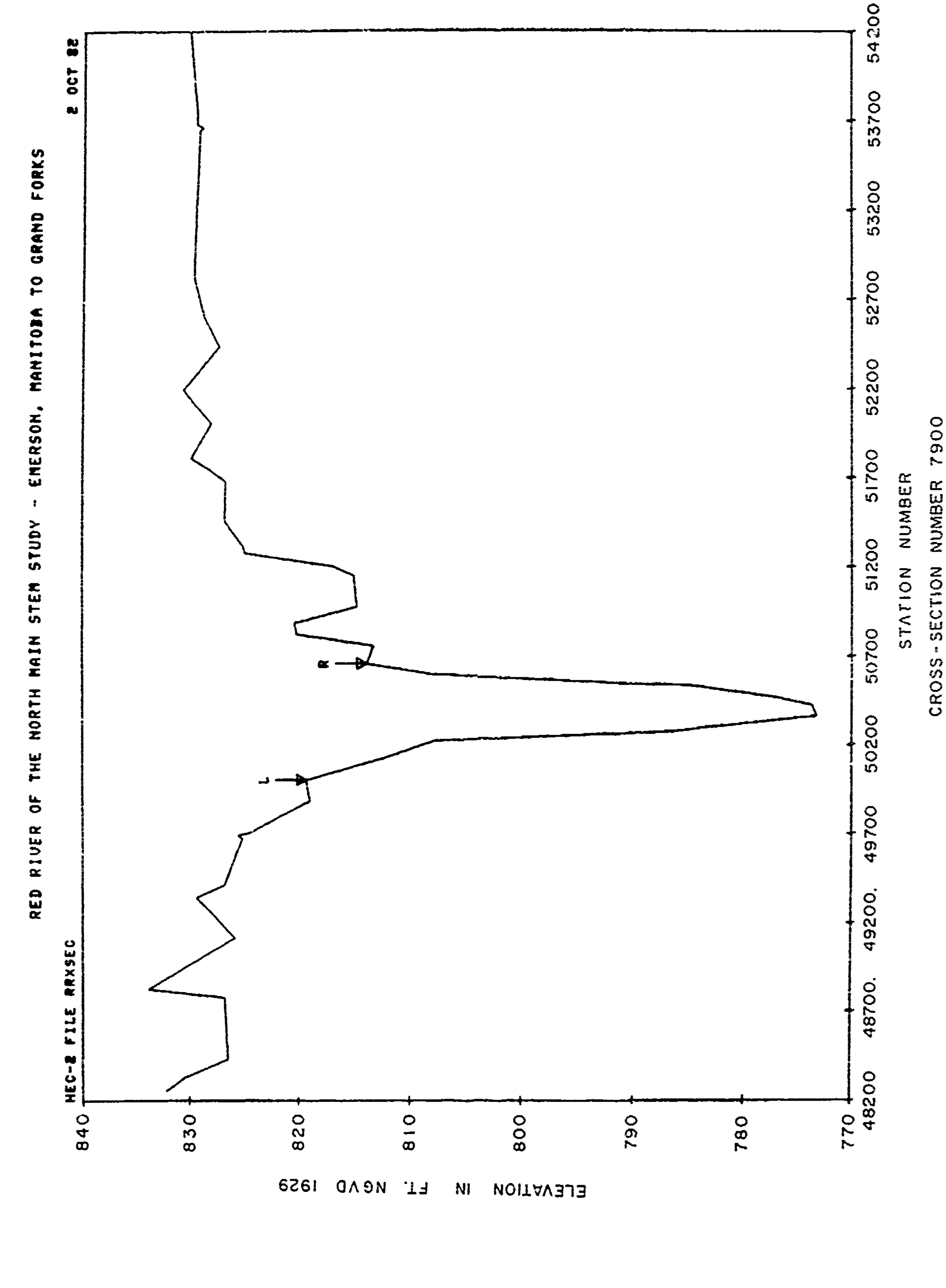
TABULATION OF CROSS-SECTION GEOMETRIC DATA AND RIVER MILEAGE FOR THE RED RIVER OF THE NORTH MAIN STEM FROM EMERSON TO GRAND FORKS, ND.

CROSS SECTION NUMBER	RIVER MILE	CHANNEL LENGTH (FEET)	THALWEG ELEV	LEFT BANK ELEV	LEFT BANK STA	RIGHT BANK ELEV	RIGHT BANK STA	CHANNEL TOPWID (FEET)	SECTION TOPWID-NATURAL
1900	187.61	8053.0	747.20	786.10	50000.0	788.90	50867.0	867.0	30000.0
2000	189.52	10115.0	747.66	786.09	50000.0	787.59	50672.0	672.0	37800.0
2100	190.04	2750.0	743.34	780.50	50000.0	783.79	50650.0	650.0	33200.0
2200	192.27	11784.0	750.60	786.40	50000.0	793.80	50754.0	754.0	34900.0
2300	194.04	9329.0	748.80	788.90	50000.0	781.70	50490.0	490.0	30060.0
2400	195.92	9919.0	749.00	784.80	50000.0	789.70	50938.0	938.0	31420.0
2500	197.52	8446.0	748.50	789.60	50000.0	782.20	51042.0	1042.0	34750.0
2600	200.20	14141.0	751.60	784.10	50000.0	785.70	51144.0	1144.0	21278.0
2700	202.71	13258.0	752.90	785.61	50000.0	786.10	51050.0	1050.0	20570.0
2710	203.50	4200.0	753.50	775.00	50000.0	780.00	50900.0	900.0	18000.0
2720	203.51	20.0	763.00	775.00	50000.0	780.00	50900.0	900.0	18000.0
2730	203.51	10.0	763.00	775.00	50000.0	780.00	50900.0	900.0	18000.0
2740	203.51	20.0	753.90	775.00	50000.0	780.00	50900.0	900.0	18000.0
2800	204.64	5963.0	755.10	778.83	50000.0	789.40	50841.0	841.0	17773.0
2900	206.56	10115.0	752.95	786.91	50000.0	799.27	51227.0	1227.0	24110.0
2905	206.70	0.0	752.95	786.91	50000.0	799.27	51227.0	1227.0	24110.0
2910	206.70	5.0	754.70	799.30	50000.0	800.60	51057.0	1057.0	23027.0
2920	206.71	30.0	754.70	799.30	50000.0	800.60	51057.0	1057.0	23027.0
2930	206.71	5.0	756.09	781.59	50000.0	791.73	50781.0	781.0	24580.0
3000	206.77	343.0	756.09	781.59	50000.0	791.73	50781.0	781.0	24580.0
3100	208.21	7615.0	748.93	775.56	50000.0	781.92	50800.0	800.0	17310.0
3200	210.13	10119.0	755.40	779.90	50000.0	777.50	50632.0	632.0	17719.0
3300	212.12	10504.0	756.39	785.17	50000.0	783.89	50448.0	448.0	18560.0
3400	214.37	11855.0	757.21	780.43	50000.0	781.98	50541.0	541.0	24320.0
3500	216.76	12625.0	755.33	788.84	50000.0	794.30	50690.0	690.0	29820.0
3600	218.53	9350.0	754.40	790.90	50000.0	791.30	5043[illegible]	430.0	28200.0
3700	220.72	11568.0	757.56	781.02	50000.0	786.57	5045[illegible]	452.0	20950.0
3800	221.91	6264.0	755.72	796.33	50000.0	782.81	5077[illegible]	771.0	26630.0
3900	225.01	16383.0	755.30	790.70	50000.0	790.60	51181.[illegible]	1181.0	26624.0
4000	226.72	9059.0	757.80	791.30	50000.0	791.20	50743.0	743.0	31800.0
4100	229.86	16576.0	756.40	793.30	50000.0	793.90	50763.0	763.0	36575.0
4200	231.76	10023.0	757.34	793.27	50000.0	794.64	50505.0	505.0	37200.0
4300	235.96	22166.0	758.80	796.20	50000.0	793.80	51112.0	1112.0	37398.0
4310	236.07	600.0	759.20	804.20	50000.0	804.30	50410.0	410.0	35991.0
4320	236.08	26.0	759.20	804.20	50000.0	804.30	50410.0	410.0	35991.0
4400	236.16	433.0	759.10	793.80	50000.0	796.50	50850.0	850.0	36323.0
4500	237.18	5382.0	759.10	794.70	50000.0	793.80	50425.0	425.0	38207.0
4600	239.44	11926.0	762.07	797.25	50000.0	798.58	51026.0	1026.0	38800.0
4700	242.46	15953.0	757.83	796.26	50000.0	794.80	51100.0	1100.0	24250.0
4800	243.88	7495.0	762.40	797.30	50000.0	796.40	50478.0	478.0	25330.0
4900	245.46	8362.0	765.20	799.60	50000.0	799.50	50890.0	890.0	30035.0
4922	247.17	9021.0	762.80	795.90	50000.0	791.70	50346.0	346.0	30035.0
5000	248.94	9334.0	764.49	800.67	50000.0	798.05	50986.0	986.0	32590.0

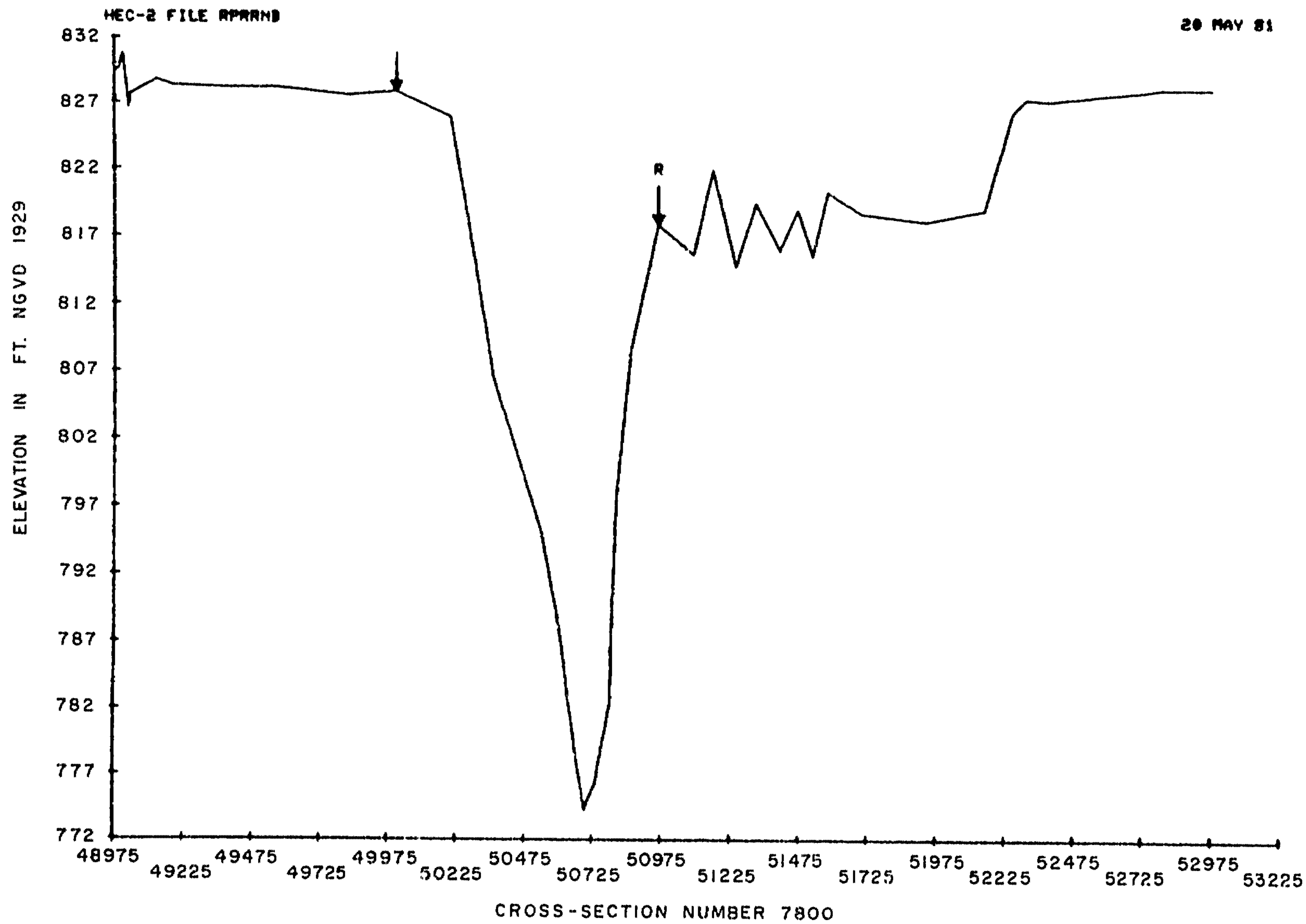
TABLE 8

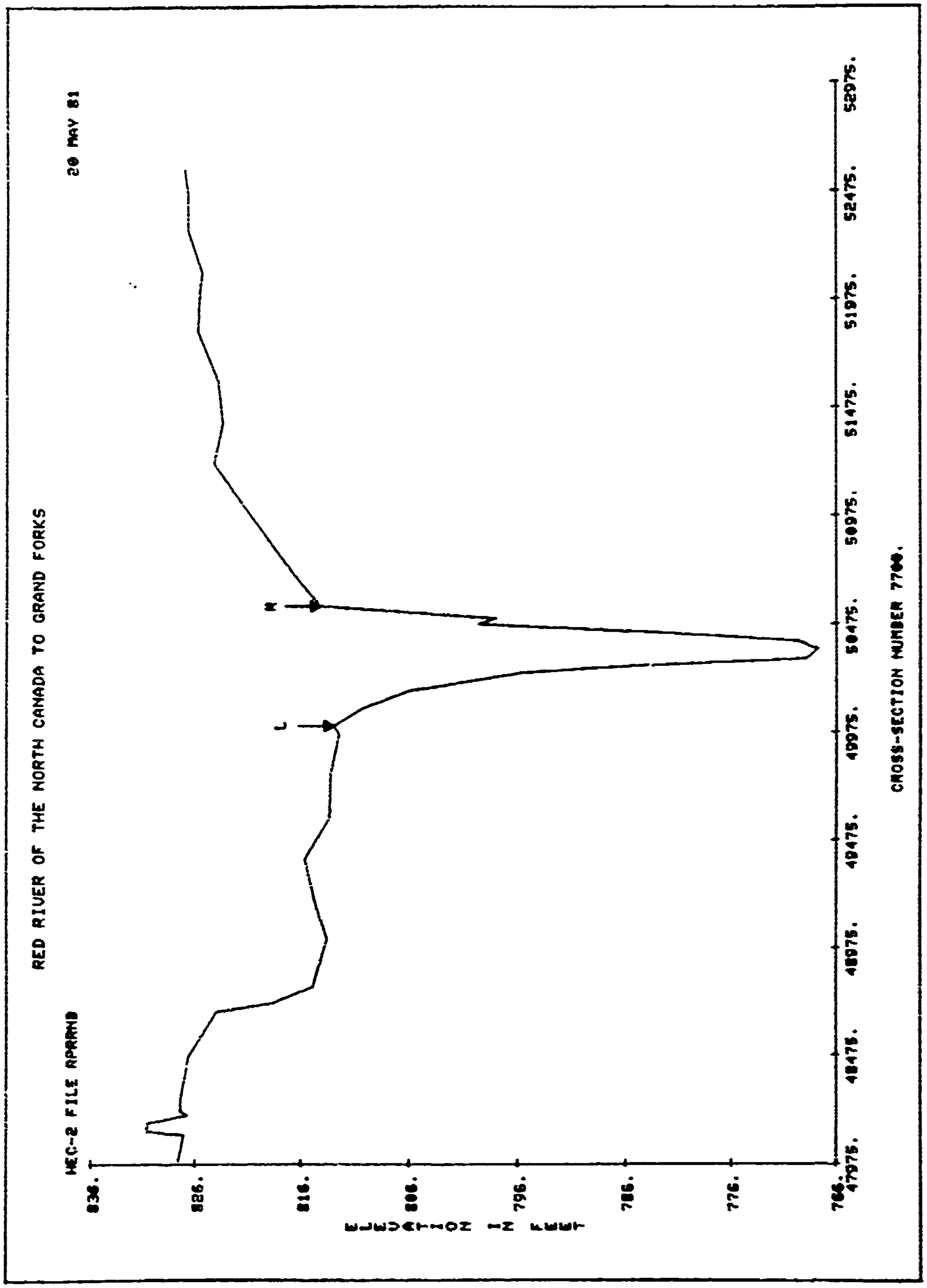
TABULATION OF CROSS-SECTION GEOMETRIC DATA AND RIVER MILEAGE FOR THE RED RIVER OF THE NORTH MAIN STEM FROM EMERSON TO GRAND FORKS, ND.

CROSS SECTION NUMBER	RIVER MILE	CHANNEL LENGTH (FEET)	THALWEG ELEV	LEFT BANK ELEV	LEFT BANK STA	RIGHT BANK ELEV	RIGHT BANK STA	CHANNEL TOPWID (FEET)	SECTION TOPWID-NATURAL
5100	252.76	20181.0	762.40	801.50	50000.0	804.20	50913.0	913.0	28760.0
5200	254.91	11340.0	765.50	800.70	50000.0	803.40	50692.0	692.0	28200.0
5300	258.22	17491.0	768.20	798.10	50000.0	801.60	51002.0	1002.0	28792.0
5400	259.81	8362.0	760.92	805.42	50000.0	793.72	50339.0	339.0	30139.0
5500	262.06	11916.0	768.00	833.10	50000.0	797.20	50586.0	586.0	27479.0
5600	266.19	21816.0	767.40	800.70	50000.0	799.40	50567.0	567.0	29191.0
5650	269.69	18443.0	770.30	801.36	50000.0	808.16	50674.0	674.0	32491.0
5670	270.20	2706.0	770.30	801.50	50000.0	808.30	50674.0	674.0	30936.0
5700	270.74	2876.0	768.80	794.60	50000.0	794.50	50569.0	569.0	30936.0
5800	271.18	2307.0	759.70	805.10	50000.0	803.40	50611.0	611.0	31389.0
5805	271.20	115.0	759.90	805.30	50000.0	803.60	50611.0	611.0	31389.0
5810	271.20	5.0	762.57	817.27	50000.0	816.67	50792.0	792.0	29933.0
5820	271.21	33.0	762.57	817.27	50000.0	816.67	50792.0	792.0	29933.0
5900	271.23	100.0	759.50	808.30	50000.0	802.20	50570.0	570.0	27775.0
5910	271.24	75.0	768.40	818.89	50000.0	818.76	50581.0	581.0	33380.0
5920	271.25	48.0	768.40	818.89	50000.0	818.76	50581.0	581.0	33380.0
5930	271.26	50.0	759.50	808.30	50000.0	802.20	50570.0	570.0	27775.0
6000	271.28	110.0	765.00	806.70	50000.0	804.40	50622.0	622.0	22200.0
6100	271.94	3506.0	772.50	802.30	50000.0	806.10	50587.0	587.0	20800.0
6200	272.87	4871.0	772.90	805.60	50000.0	810.10	50635.0	635.0	19500.0
6300	275.82	15586.0	770.40	805.50	50000.0	805.30	50686.0	686.0	24500.0
6305	276.25	2259.0	770.40	805.50	50000.0	805.40	50686.0	686.0	24500.0
6310	276.26	50.0	770.40	805.50	50000.0	805.30	50686.0	686.0	21100.0
6315	276.26	50.0	770.40	805.60	50000.0	805.70	50686.0	686.0	24500.0
6400	277.11	4460.0	771.40	804.80	50000.0	803.10	50642.0	642.0	19460.0
6500	279.80	14223.0	768.70	806.90	50000.0	808.20	50413.0	413.0	19500.0
6600	280.63	4384.0	773.70	805.90	50000.0	799.40	50328.0	328.0	16254.0
6700	281.74	5839.0	768.40	807.90	50000.0	809.90	50356.0	356.0	16010.0
6705	282.24	2661.0	768.40	807.90	50000.0	809.90	50356.0	356.0	16010.0
6710	282.25	50.0	768.40	807.80	50000.0	813.60	50356.0	356.0	15450.0
6715	282.26	50.0	768.40	807.90	50000.0	809.90	50356.0	356.0	21210.0
6800	283.16	4739.0	770.20	809.50	50000.0	805.40	50788.0	788.0	19258.0
6900	284.65	7891.0	774.80	811.60	50000.0	816.50	50368.0	368.0	18889.0
7000	285.76	5846.0	772.40	813.90	50000.0	803.50	50420.0	420.0	18900.6
7100	286.59	4384.0	777.10	817.10	50000.0	817.70	50788.0	788.0	15758.0
7200	287.83	6527.0	769.50	817.40	50000.0	821.00	50497.0	497.0	13450.0
7300	288.92	5747.0	772.00	808.10	50000.0	804.90	50414.0	414.0	6412.0
7400	290.80	9938.0	773.00	806.20	50000.0	810.80	50500.0	500.0	7880.0
7500	292.09	6820.0	777.00	819.00	50000.0	821.30	50730.0	730.0	4308.0
7600	292.92	4384.0	770.40	818.30	50000.0	810.90	50630.0	630.0	3200.0
7700	294.29	7210.0	767.62	812.85	50000.0	814.07	50555.0	555.0	5510.0
7790	295.70	7470.0	773.15	826.86	50000.0	816.72	50960.0	960.0	4488.0
7800	296.00	1584.0	774.20	827.91	50000.0	817.77	50960.0	960.0	4488.0


RED RIVER OF THE NORTH MAIN STEM STUDY - EMERSON, MANITOBA TO GRAND FORKS
HEC-2 FILE RRXSEC
2 OCT 82
ELEVATION IN FT. NGVD 1929
840
830
820
810
800
790
780
770
48200
48700.
49200.
49700
50200
50700
51200
51700
52200
52700
53200
53700
54200
L
R
STATION NUMBER
CROSS-SECTION NUMBER 7900

RED RIVER OF THE NORTH CANADA TO GRAND FORKS




HEC-2 FILE RPARMD
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
20 MAY 81
ELEVATION IN FEET
836.
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816.
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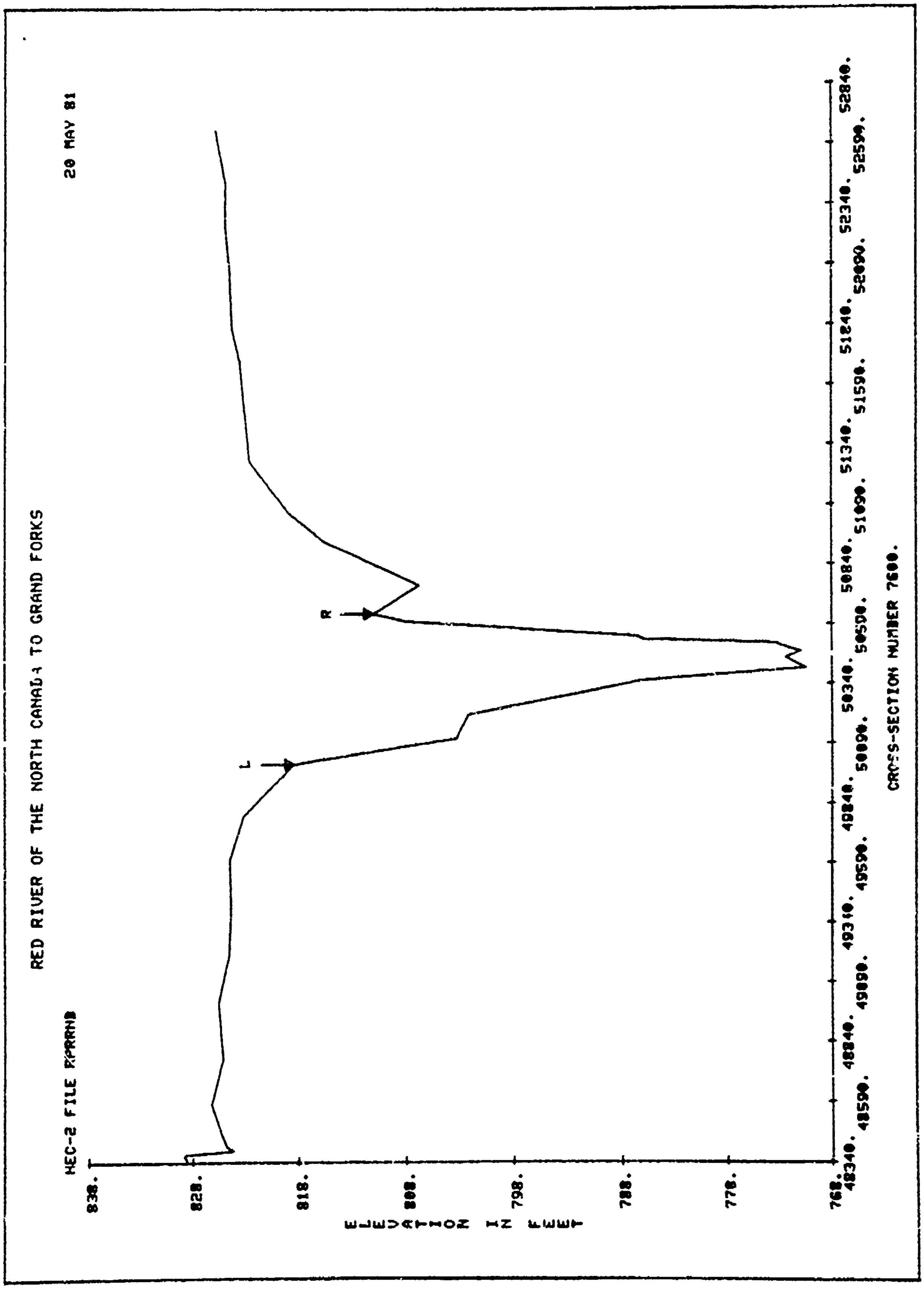
796.
786.
776.
766.
47975.
48475.
48975.
49475.
49975.
50475.
50975.
51475.
51975.
52475.
52975.
L
R
CROSS-SECTION NUMBER 7700.



RED RIVER OF THE NORTH CANADA TO GRAND FORKS
20 MAY 81
HEC-2 FILE
ELEVATION IN FEET
838.
828.
818.
808.
798.
788.
778.
768.
48340.
48590.
48840.
49090.
49310.
49590.
49840.
50090.
50340.
50590.
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51590.
51840.
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52840.
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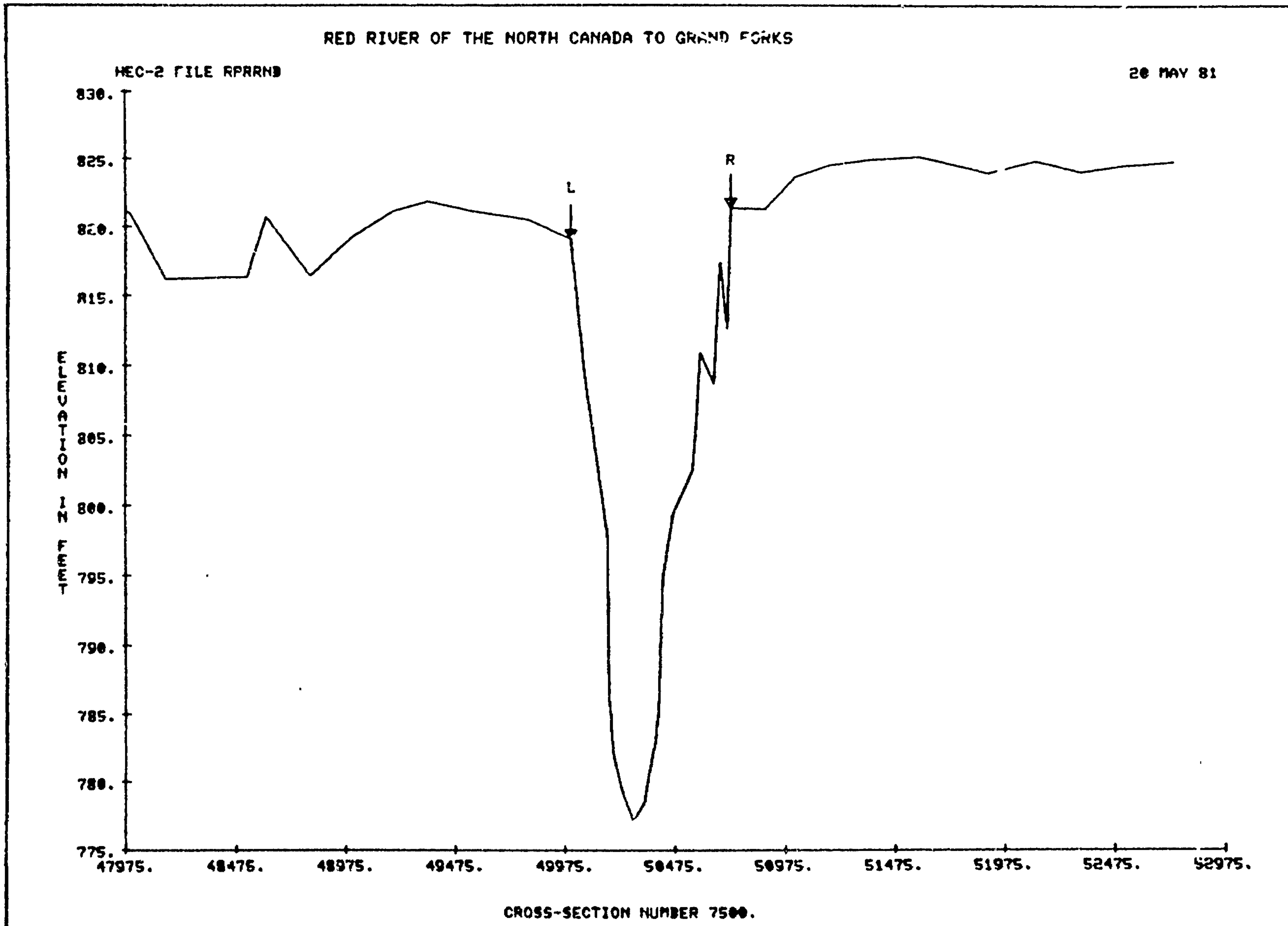
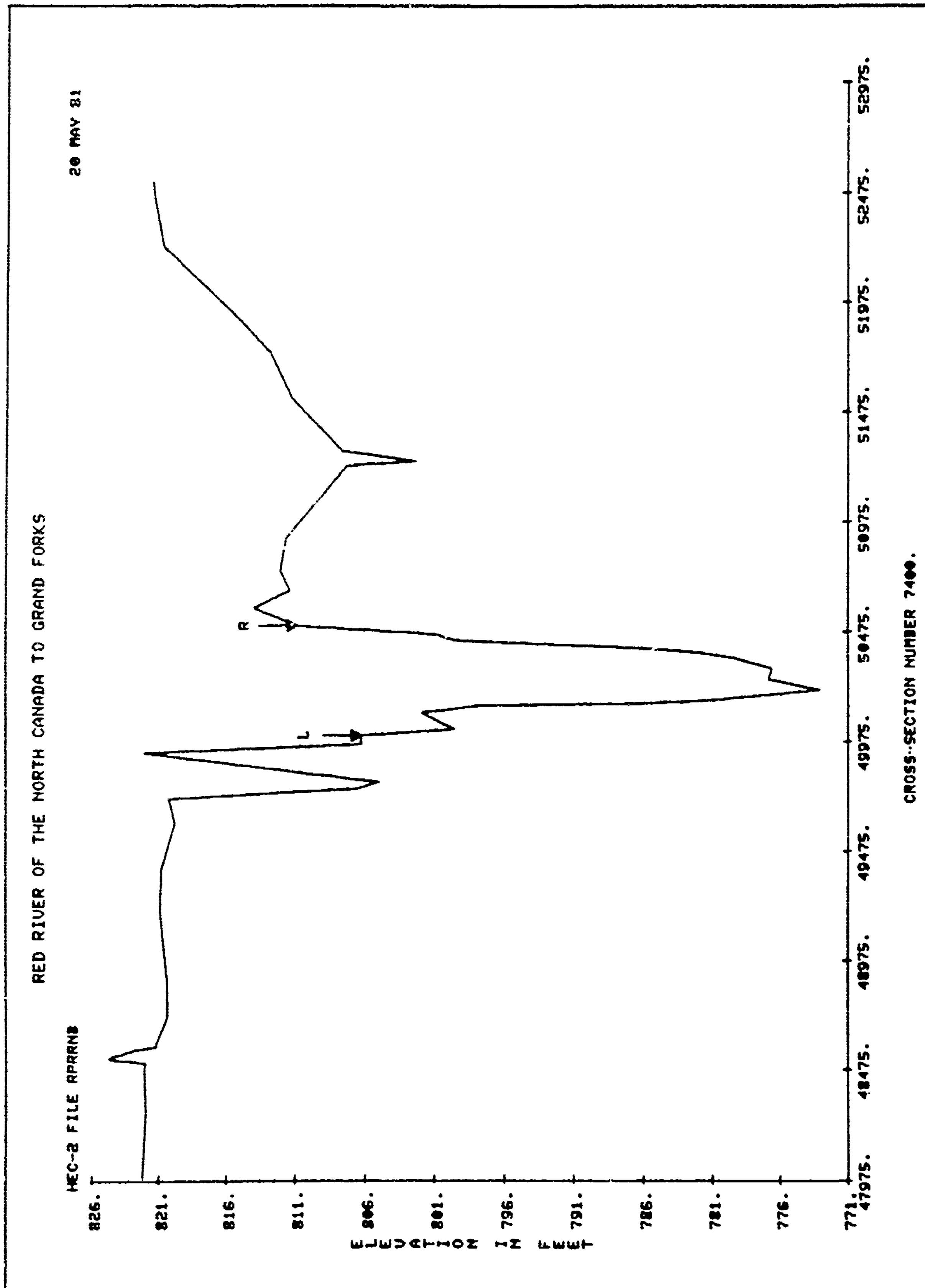
R
CROSS-SECTION NUMBER 7600.



RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRNB
20 MAY 81
ELEVATION IN FEET
830.
825.
820.
815.
810.
805.
800.
795.
790.
785.
780.
775.
47975.
48475.
48975.
49475.
49975.
50475.
50975.
51475.
51975.
52475.
52975.
L
R
CROSS-SECTION NUMBER 7500.



RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRNB
20 MAY 81
ELEVATION IN FEET
826.
821.
816.
811.
806.
801.
796.
791.
786.
781.
776.
771.
47975.
48475.
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L
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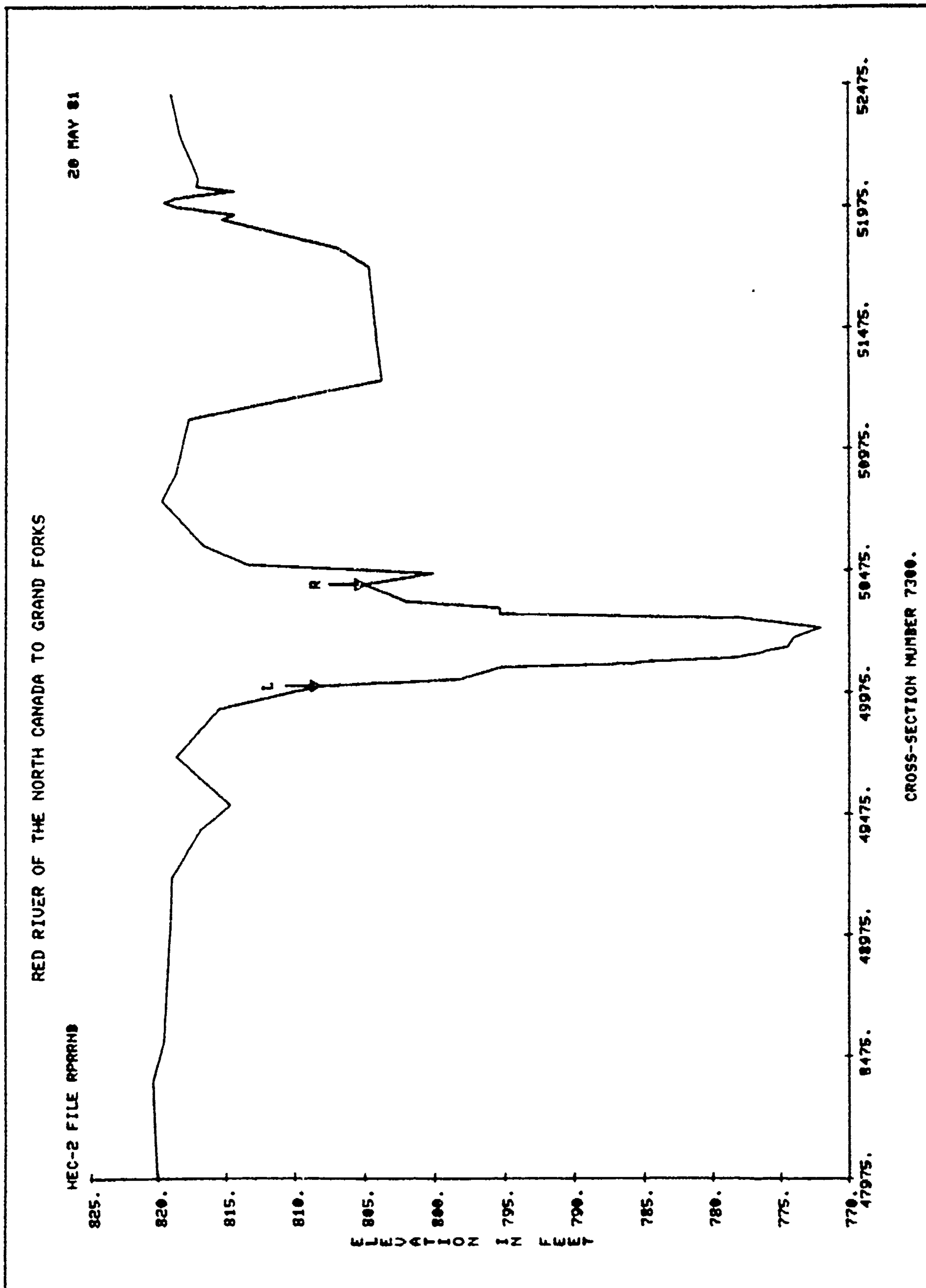

RED RIVER OF THE NORTH CANADA TO GRAND FORKS
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ELEVATION IN FEET
825.
820.
815.
810.
805.
800.
795.
790.
785.
780.
775.
770.
47975.
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49975.
50475.
50975.
51475.
51975.
52475.
L
R
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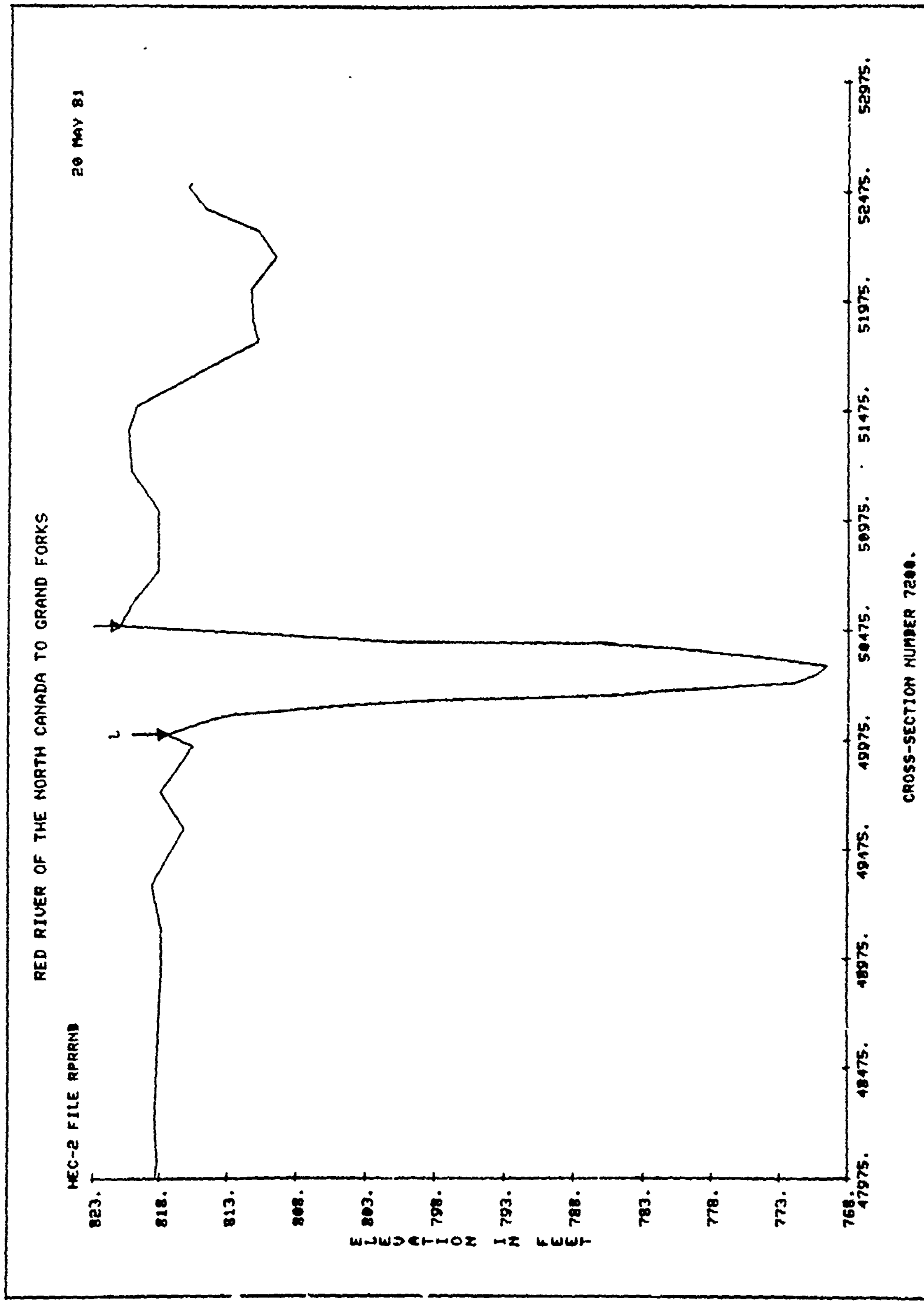

RED RIVER OF THE NORTH CANADA TO GRAND FORKS
20 MAY 81
HEC-2 FILE RPRRNB
L
ELEVATION IN FEET
823.
818.
813.
808.
803.
798.
793.
788.
783.
778.
773.
768.
47975.
48475.
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50975.
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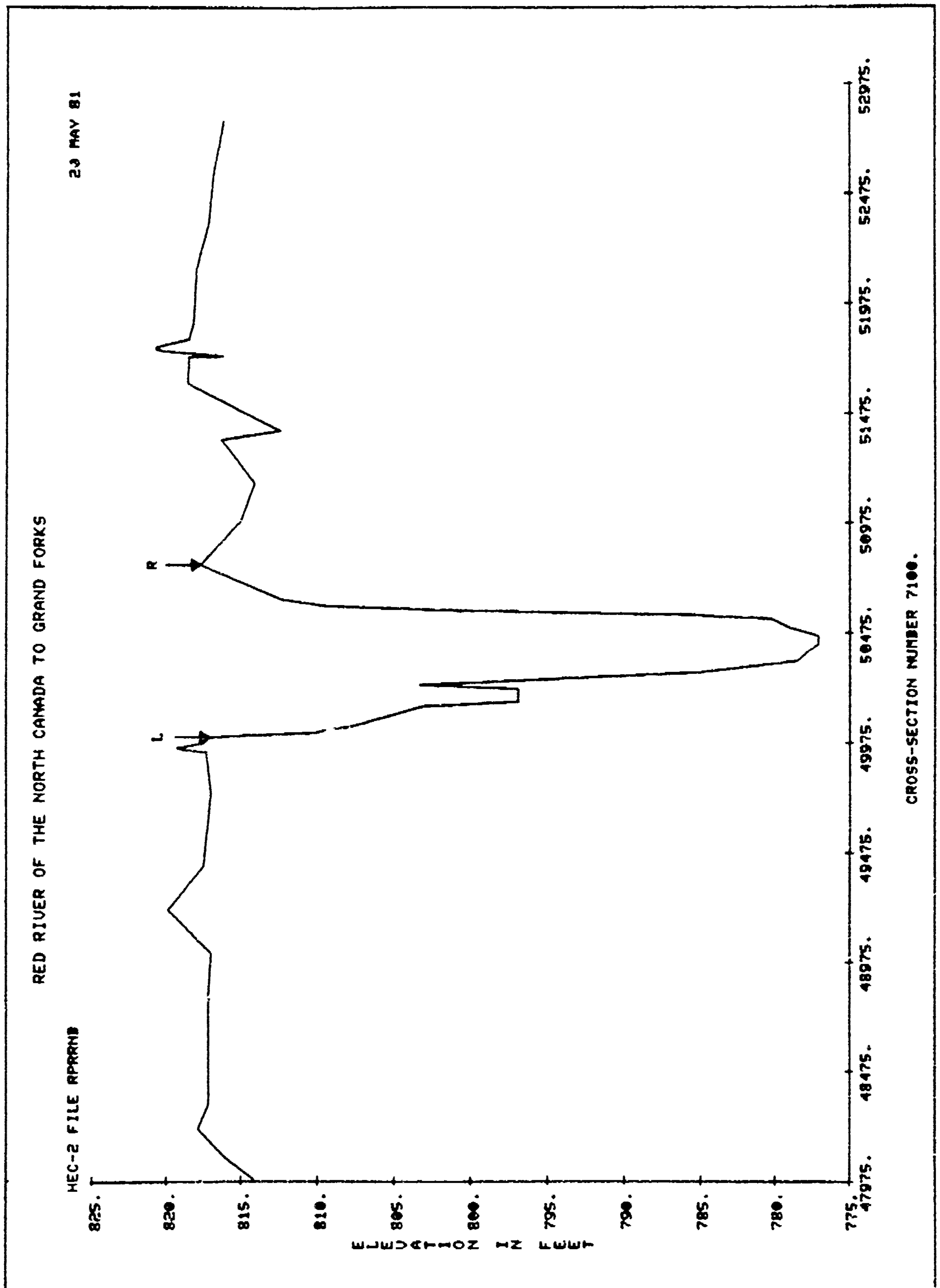
52975.
CROSS-SECTION NUMBER 7200.



RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRNB
29 MAY 81
ELEVATION IN FEET
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820.
815.
810.
805.
800.
795.
790.
785.
780.
775.
47975.
48475.
48975.
49475.
49975.
50475.
50975.
51475.
51975.
52475.
52975.
L
R
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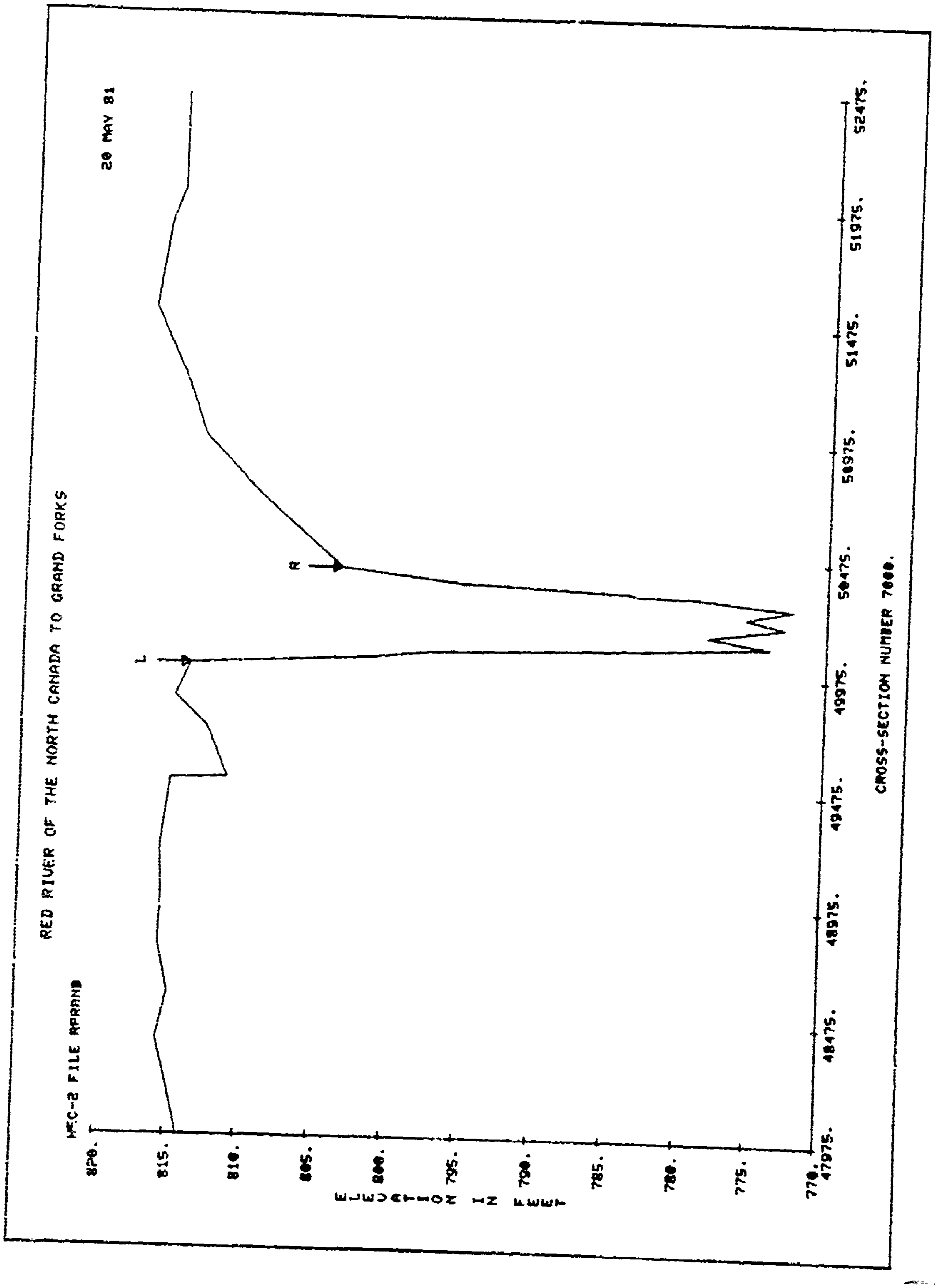
HEC-2 FILE RPRAND
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
20 MAY 81
ELEVATION IN FEET
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815.
810.
805.
800.
795.
790.
785.
780.
775.
770.
47975.
48475.
48975.
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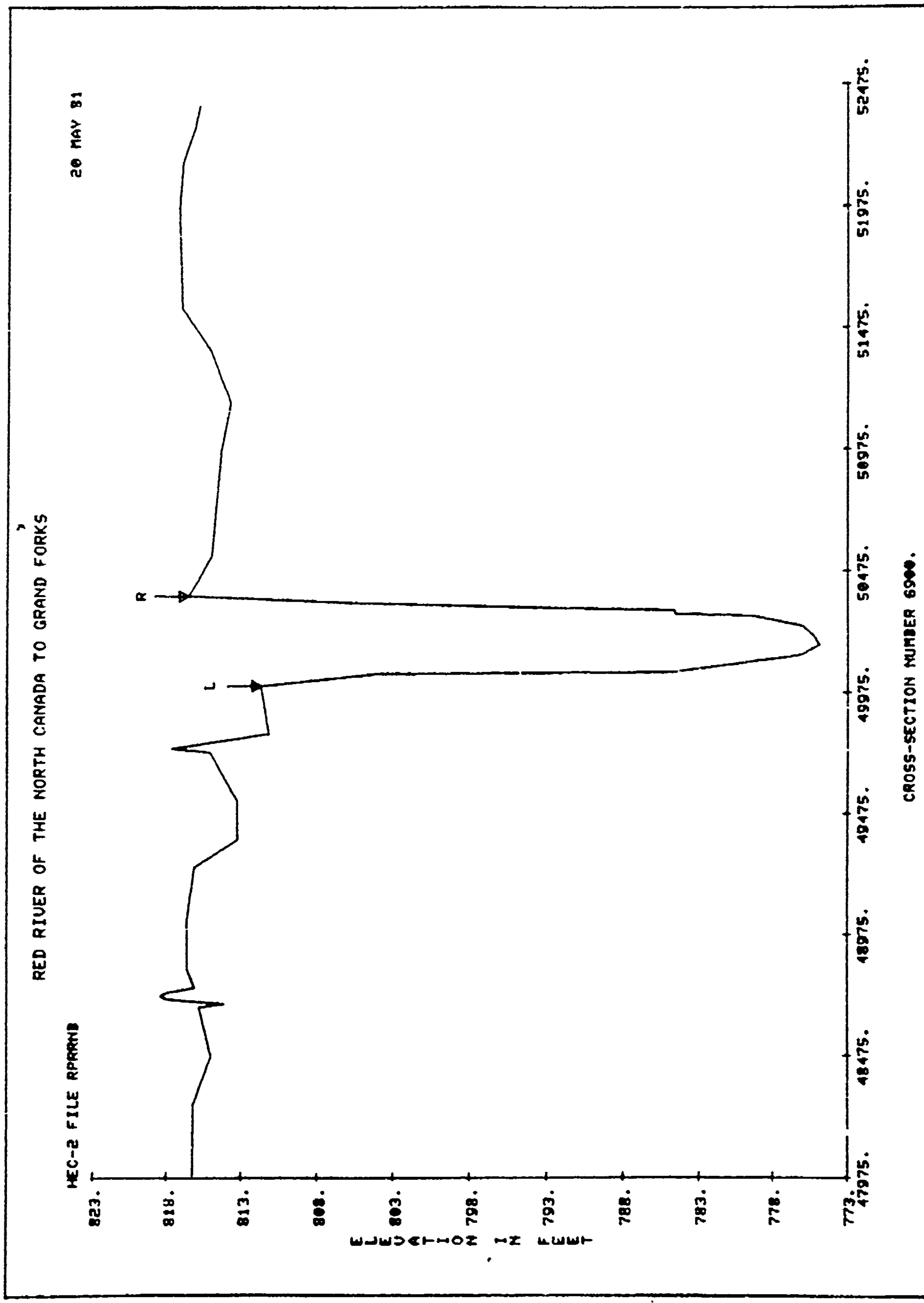
49975.
50475.
50975.
51475.
51975.
52475.
L
R
CROSS-SECTION NUMBER 7000.



RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRNB
20 MAY 81
ELEVATION IN FEET
823.
818.
813.
808.
803.
798.
793.
788.
783.
778.
773.
47975.
48475.
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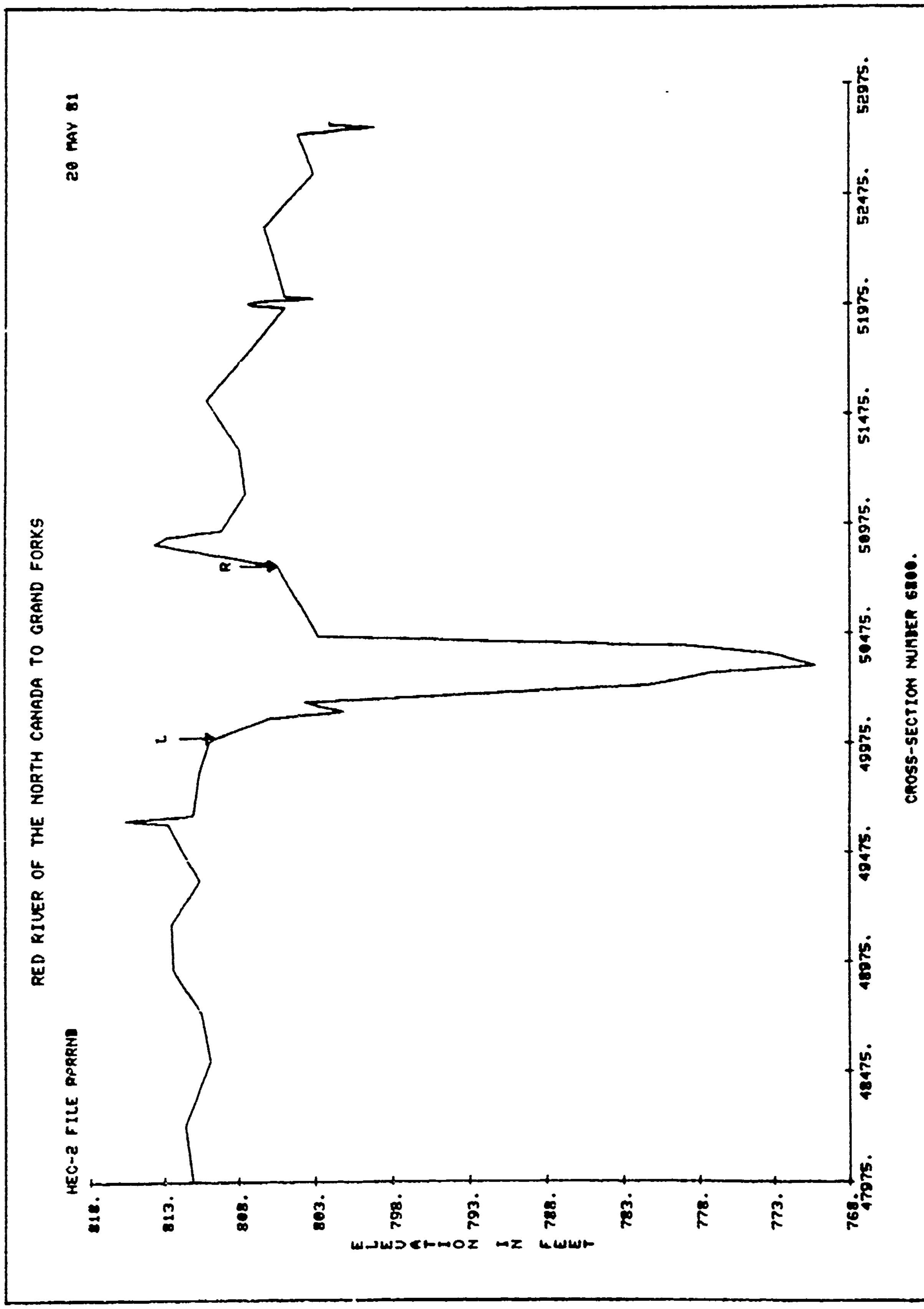
49975.
50475.
50975.
51475.
51975.
52475.
CROSS-SECTION NUMBER 6900.
L
R


HEC-2 FILE PPRRNB
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20 MAY 81
ELEVATION IN FEET
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808.
803.
798.
793.
788.
783.
778.
773.
768.
47975.
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52975.
L
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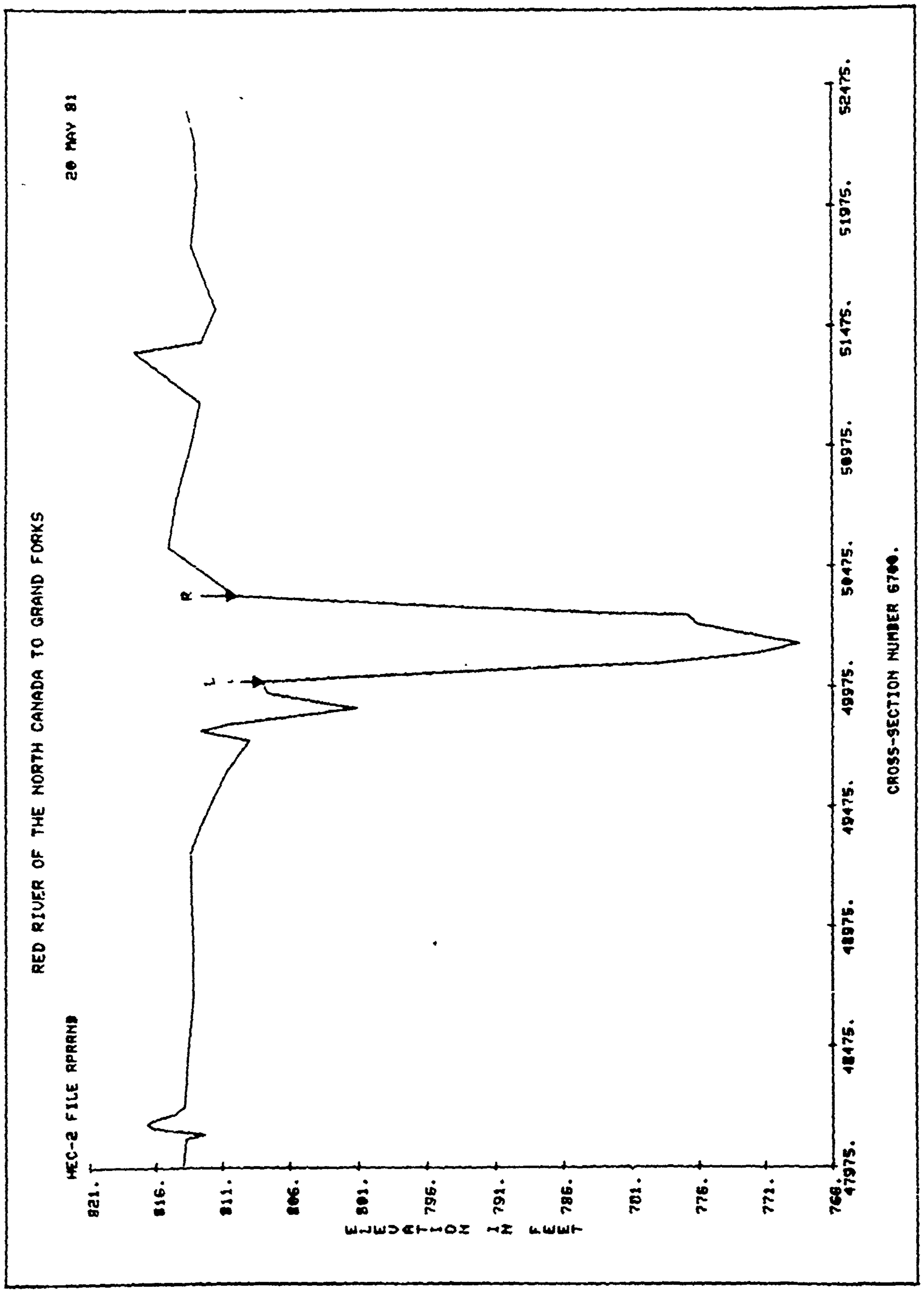

RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRAND
20 MAY 81
ELEVATION IN FEET
821.
816.
811.
806.
801.
796.
791.
786.
781.
776.
771.
766.
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48475.
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52475.
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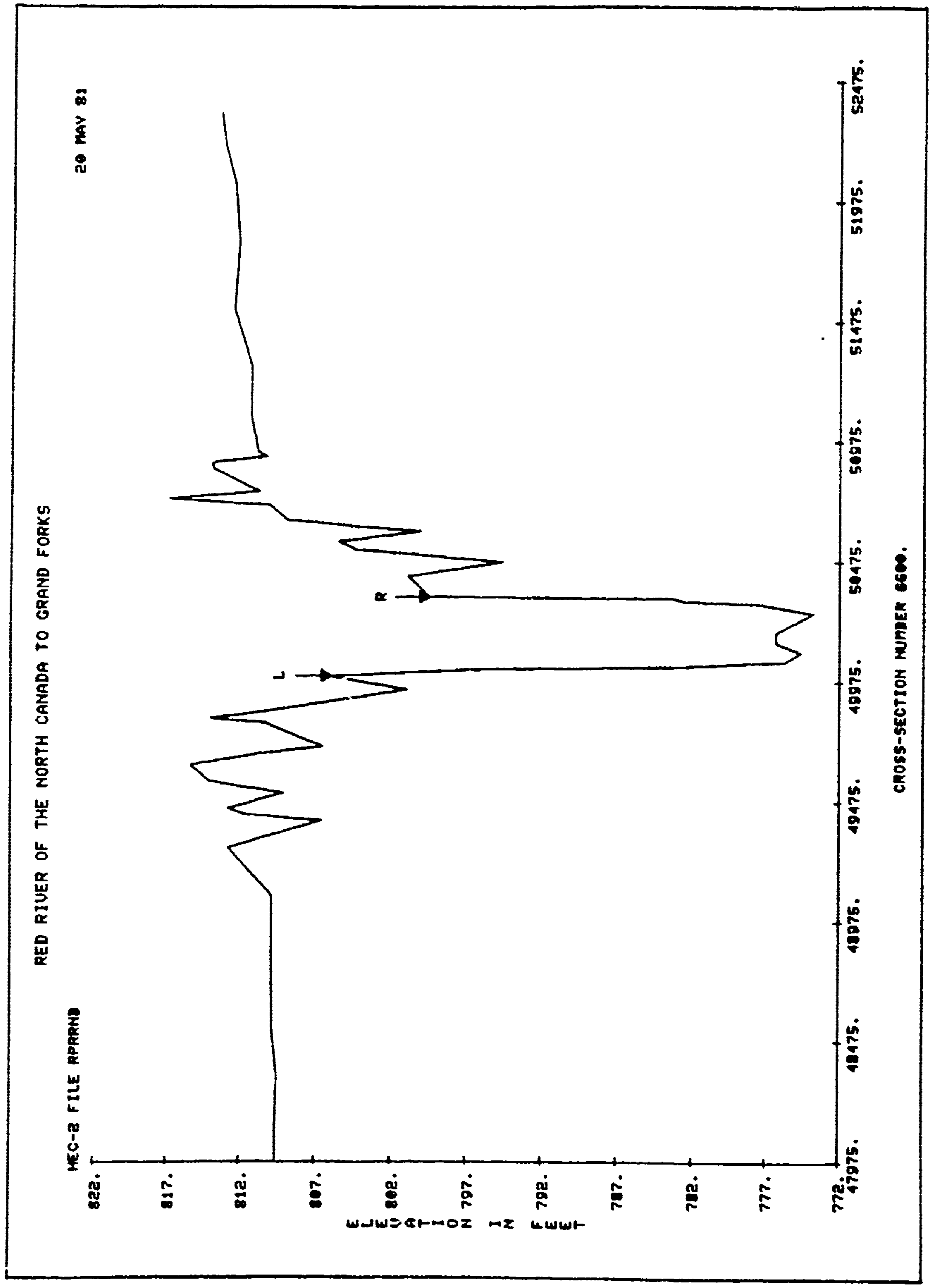

RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRNB
20 MAY 81
ELEVATION IN FEET
822.
817.
812.
807.
802.
797.
792.
787.
782.
777.
772.
47975.
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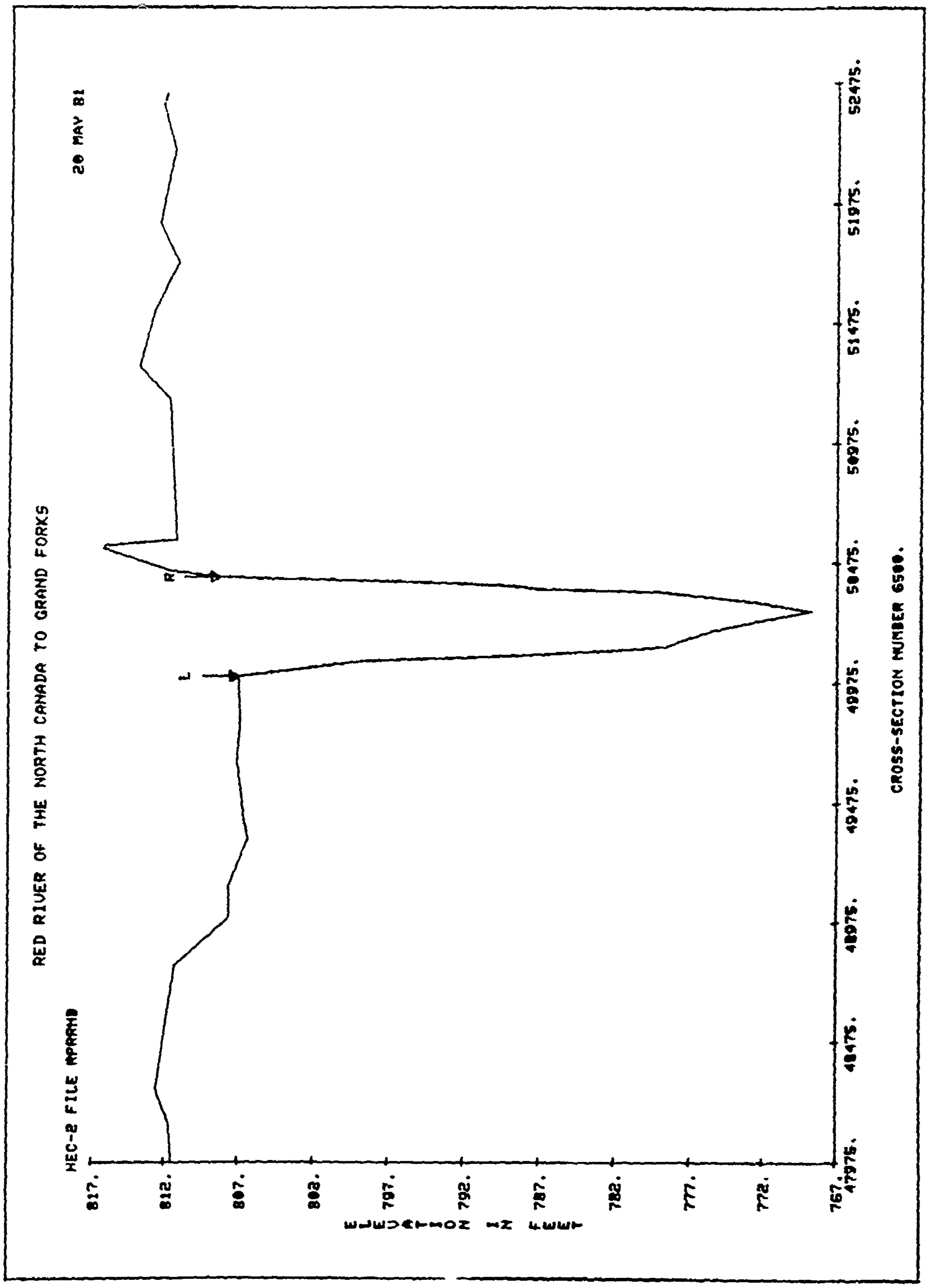
CROSS-SECTION NUMBER 8600.


RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRNB
20 MAY 81
ELEVATION IN FEET
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807.
802.
797.
792.
787.
782.
777.
772.
767.
CROSS-SECTION NUMBER 6500.
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49975.
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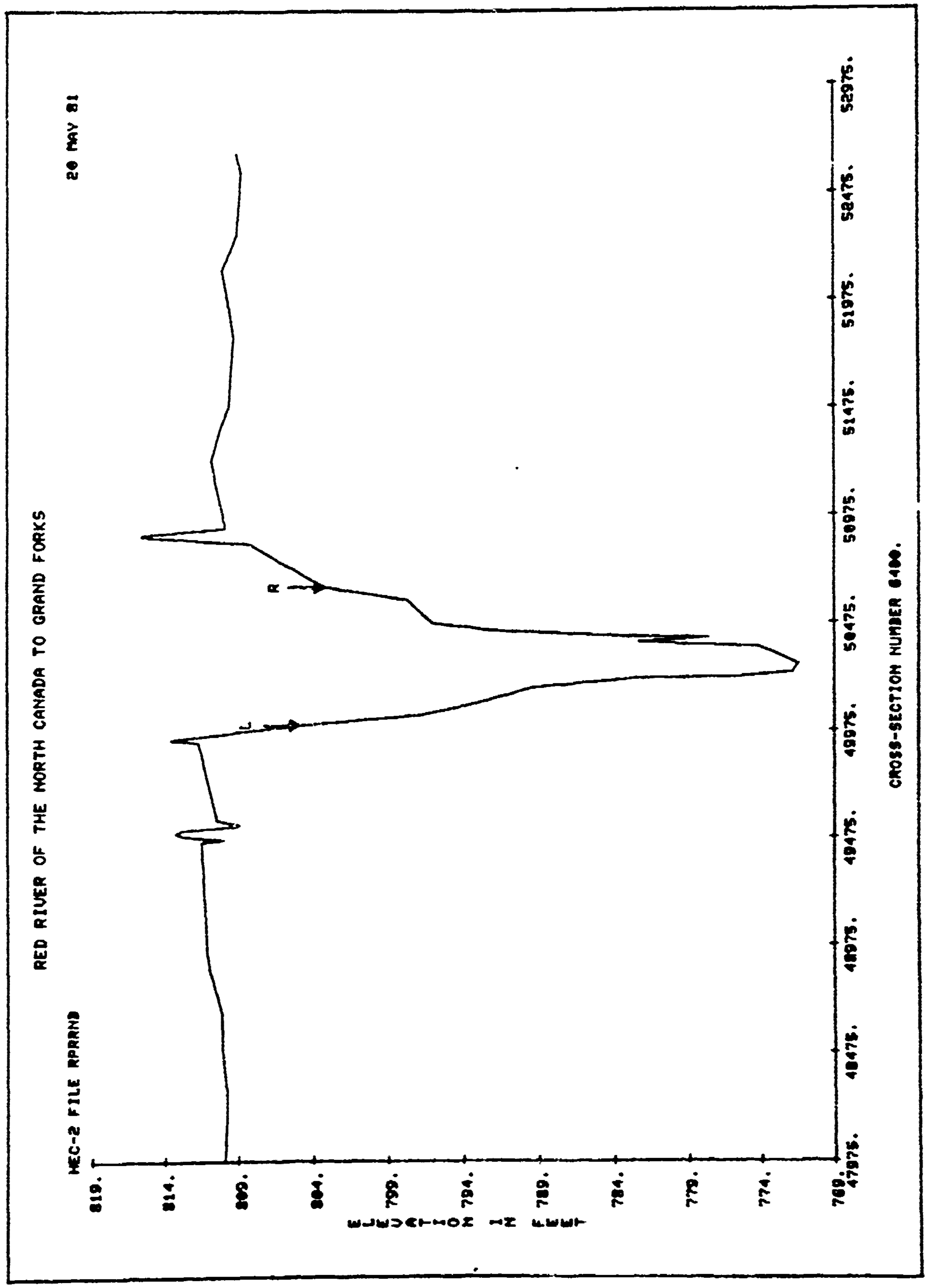
51475.
51975.
52475.
L
R


HEC-2 FILE RPRRND
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
20 MAY 81
ELEVATION IN FEET
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809.
804.
799.
794.
789.
784.
779.
774.
769.
47975.
48475.
48975.
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50975.
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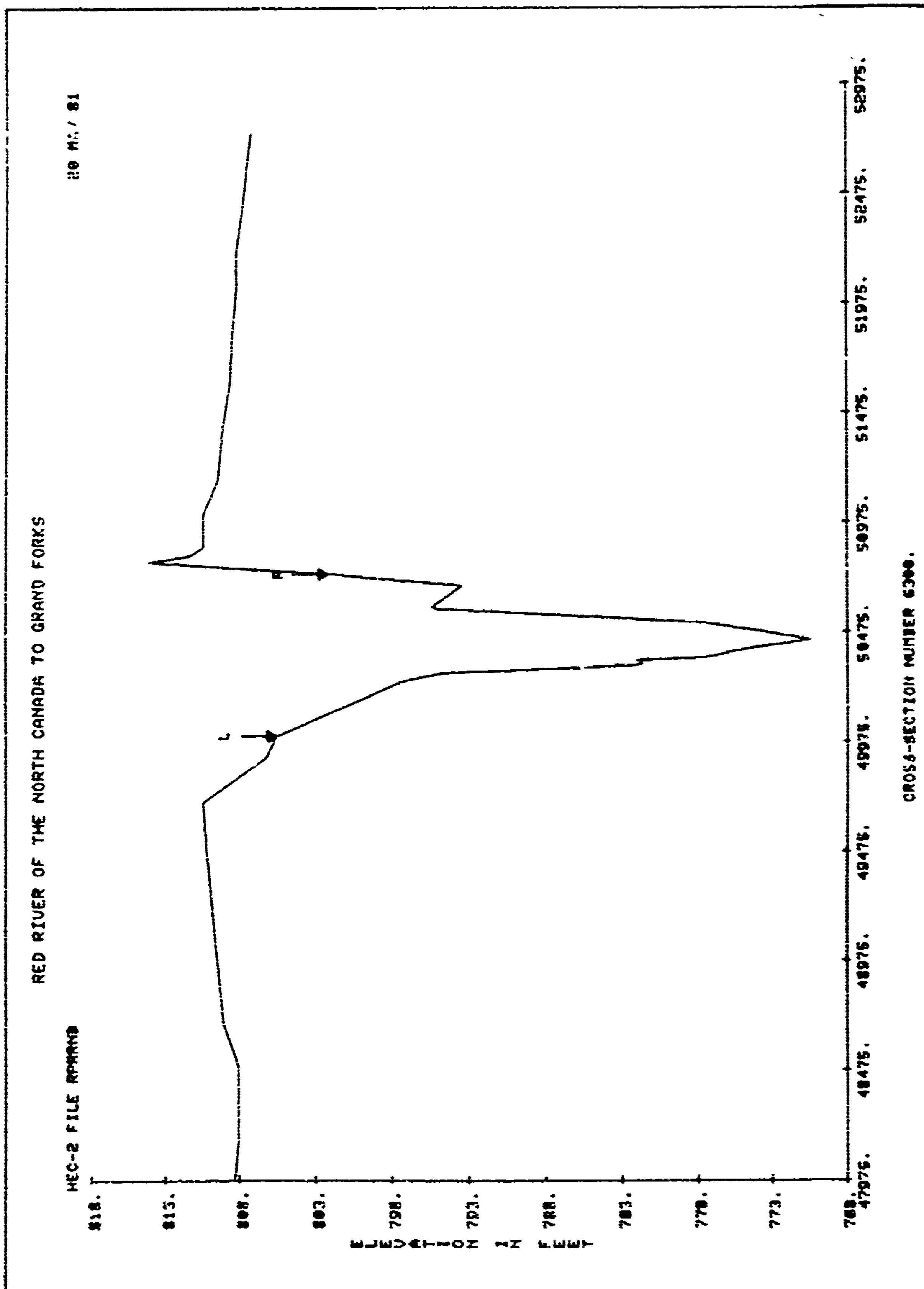
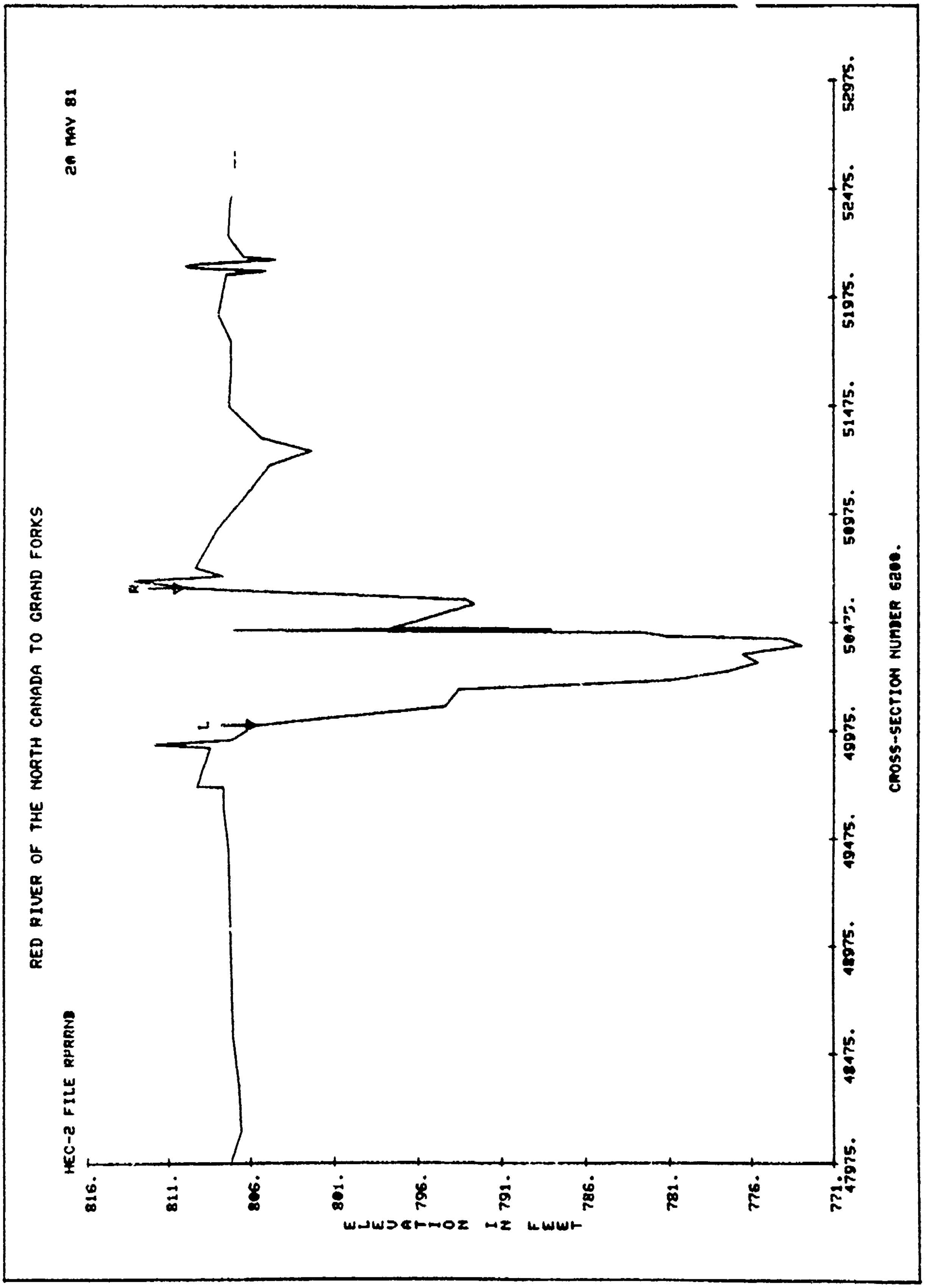
51975.
52475.
52975.
L
R
CROSS-SECTION NUMBER 6400.


HEC-2 FILE
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
ELEVATION IN FEET
818.
813.
808.
803.
798.
793.
788.
783.
778.
773.
768.
47975.
48475.
48975.
49475.
49975.
50475.
50975.
51475.
51975.
52475.
52975.
L
R
CROSS-SECTION NUMBER 6300.



RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRNB
20 MAY 81
ELEVATION IN FEET
816.
811.
806.
801.
796.
791.
786.
781.
776.
771.
47975.
48475.
48975.
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51475.
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52975.
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R
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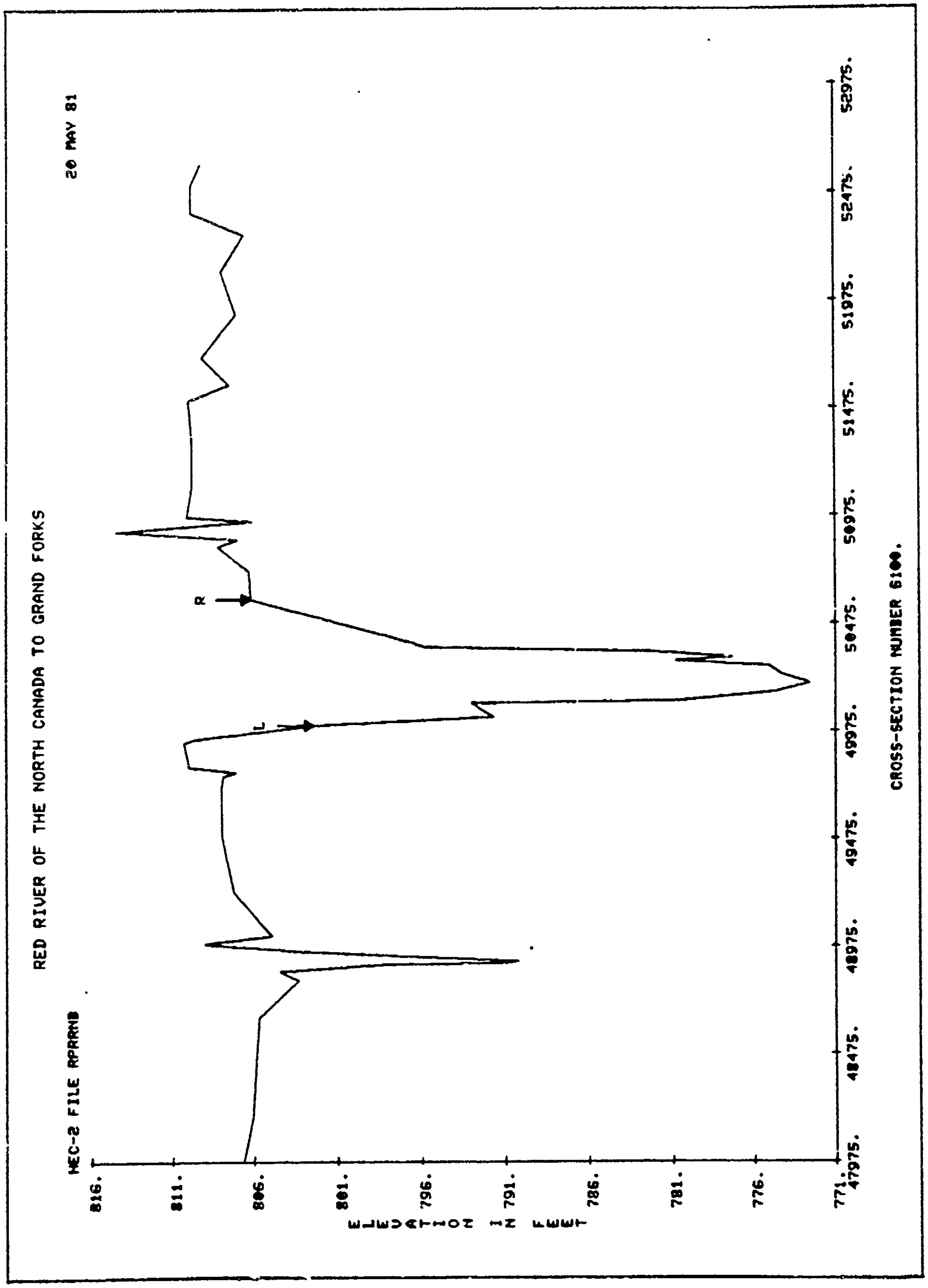
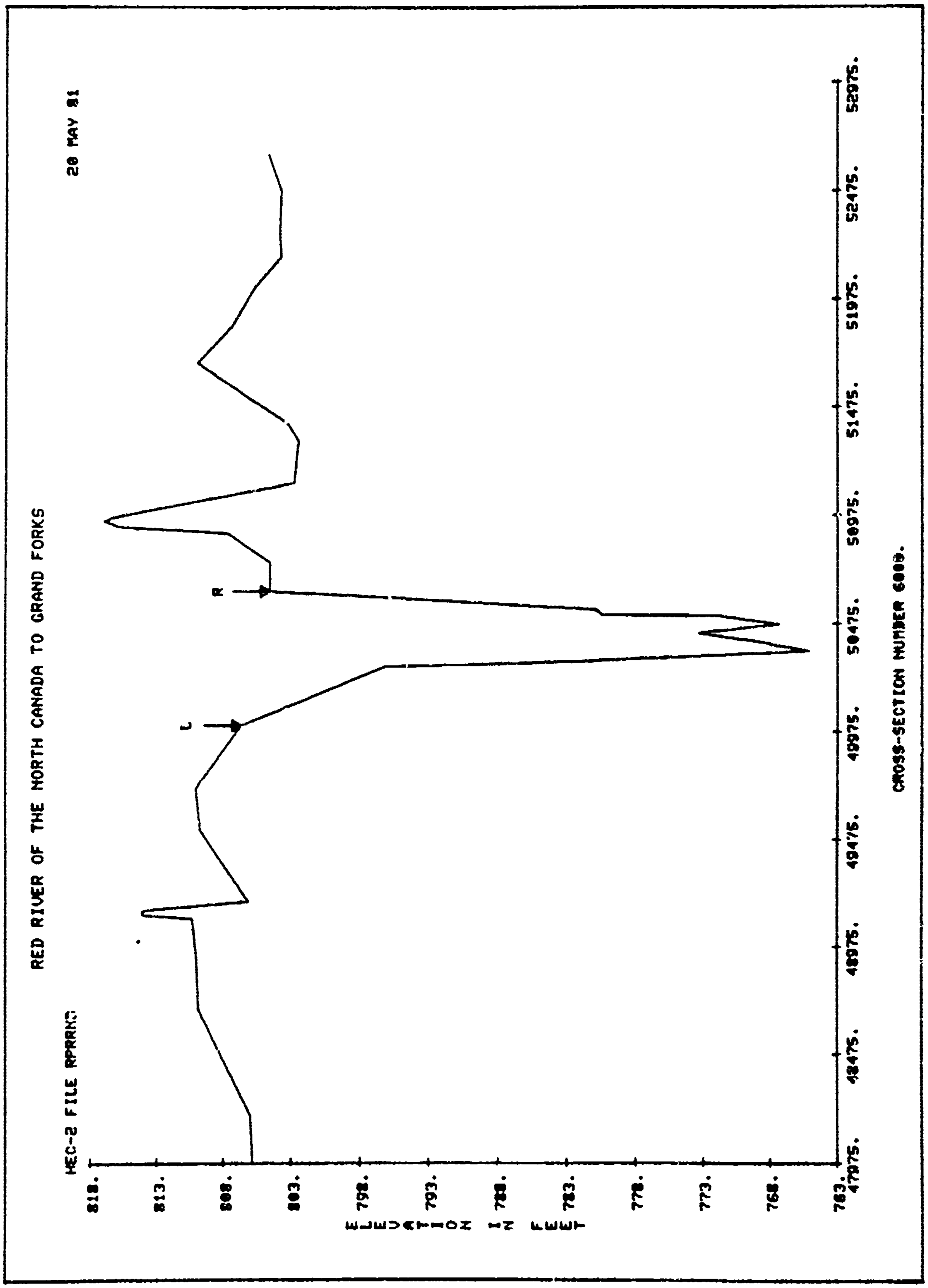


RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRNB
20 MAY 81
ELEVATION IN FEET
816.
811.
806.
801.
796.
791.
786.
781.
776.
771.
47975.
48475.
48975.
49475.
49975.
50475.
50975.
51475.
51975.
52475.
52975.
L
R
CROSS-SECTION NUMBER 6100.



RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRKS
20 MAY 81
ELEVATION IN FEET
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813.
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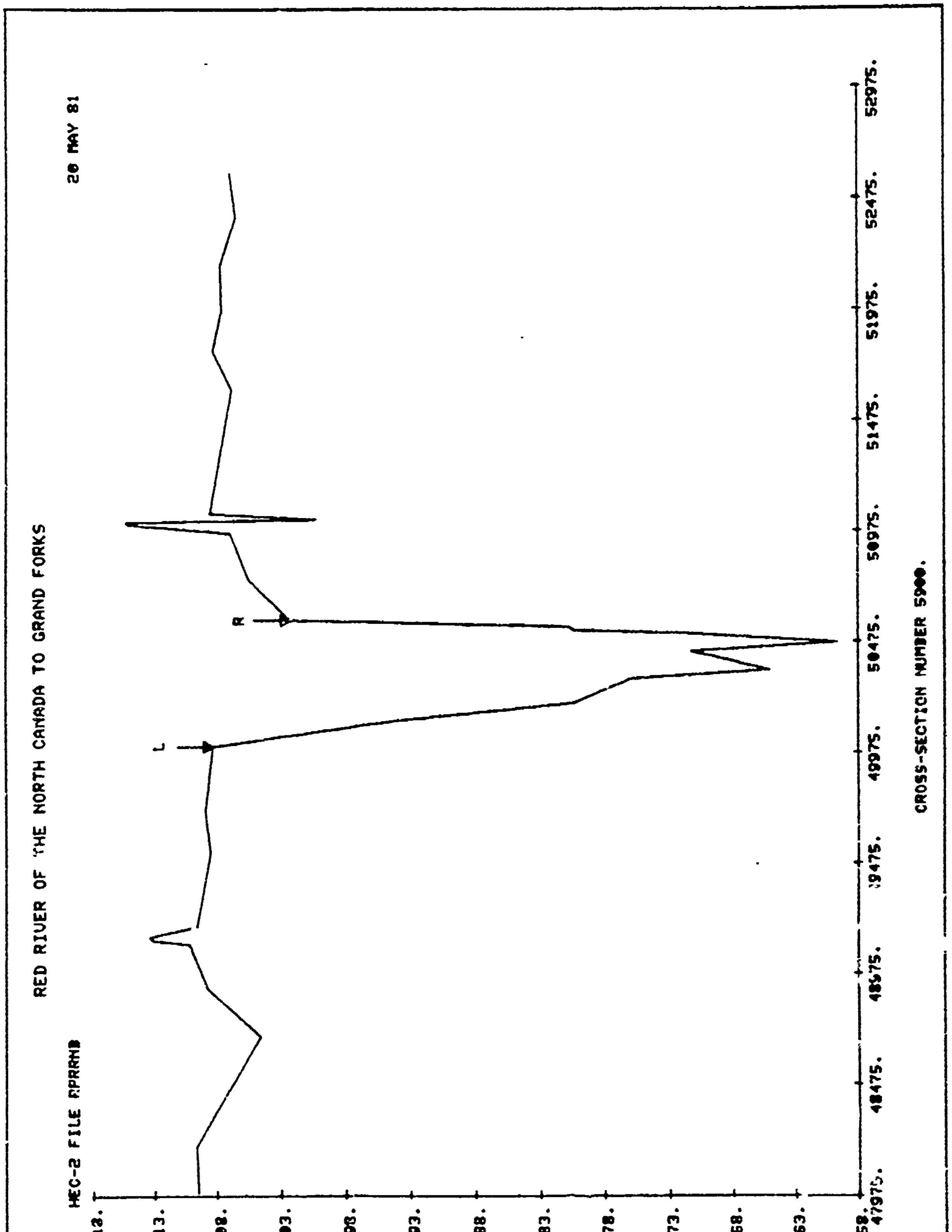
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RED RIVER OF THE NORTH CANADA TO GRAND FORKS
20 MAY 81
ELEVATION IN FEET
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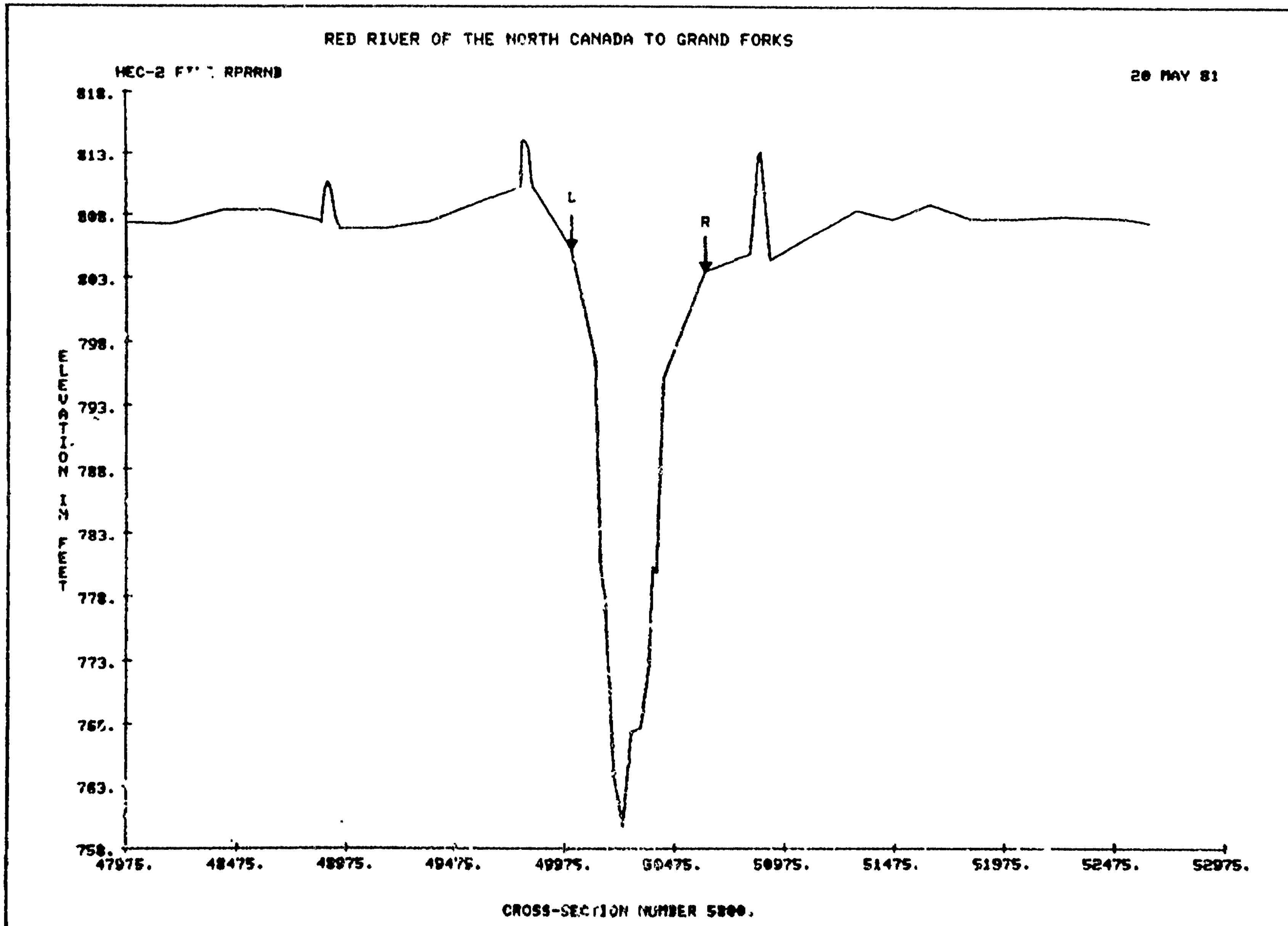
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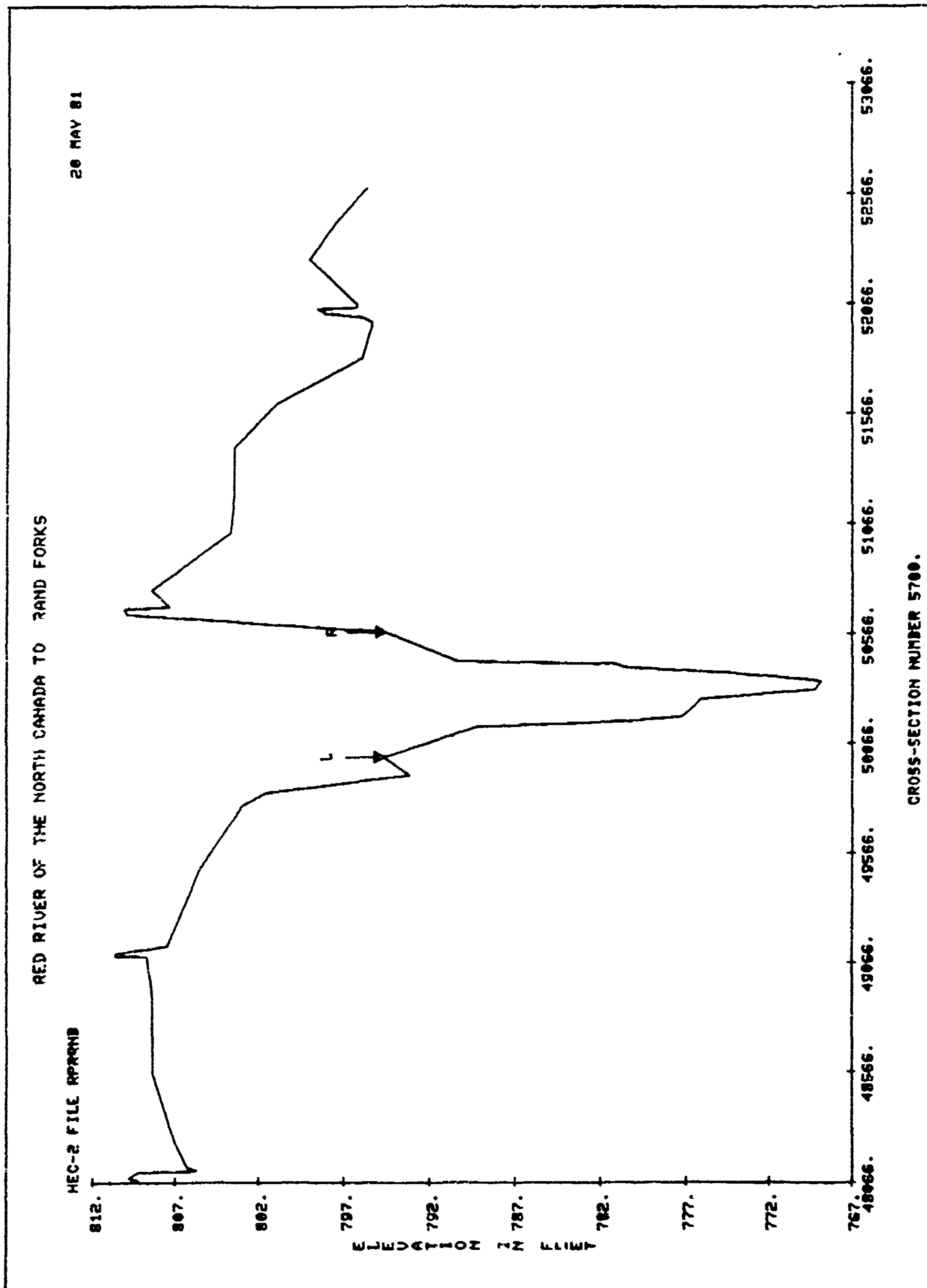

RED RIVER OF THE NORTH CANADA TO RAND FORKS
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HEC-2 FILE
ELEVATION IN FEET
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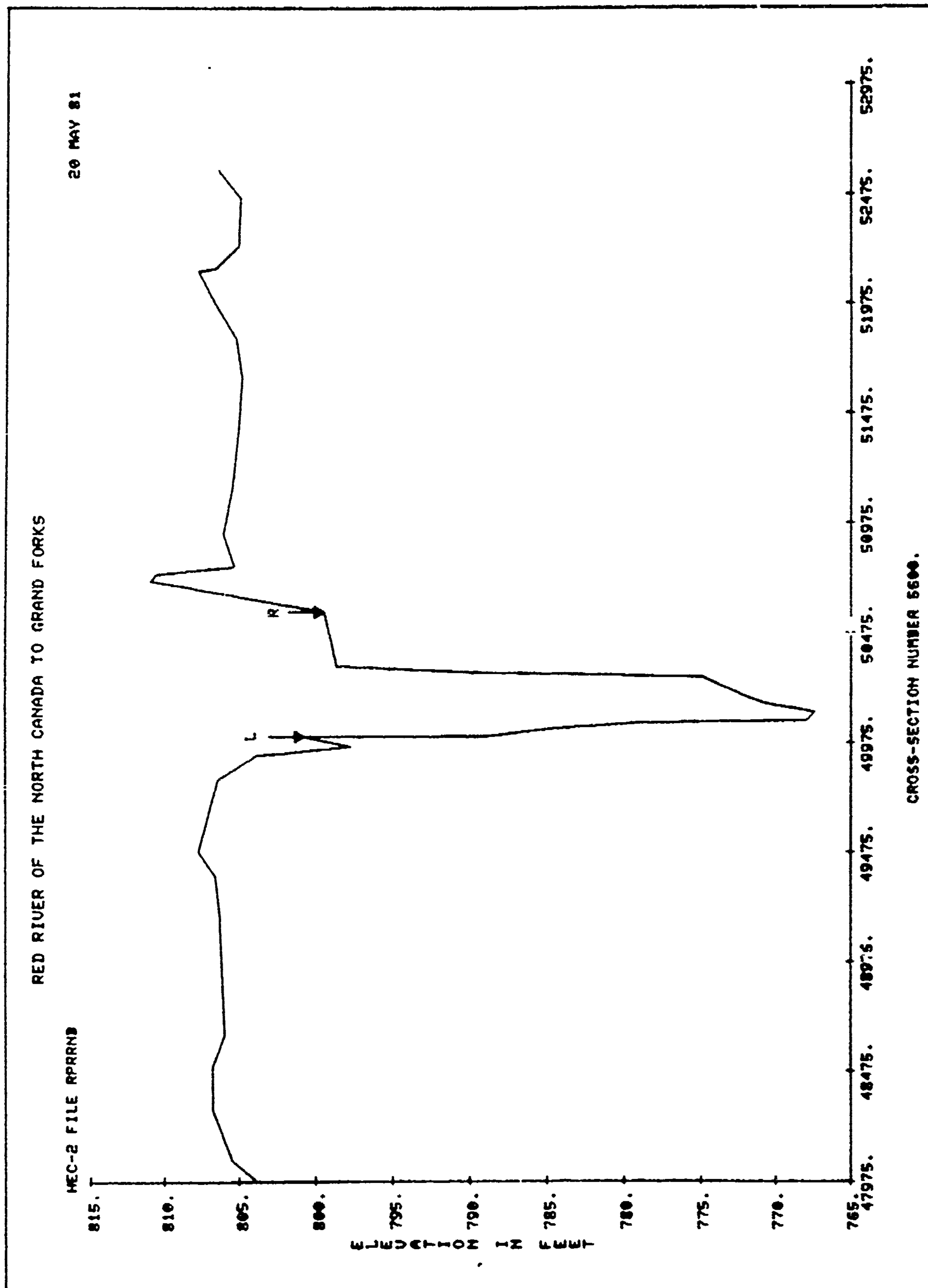
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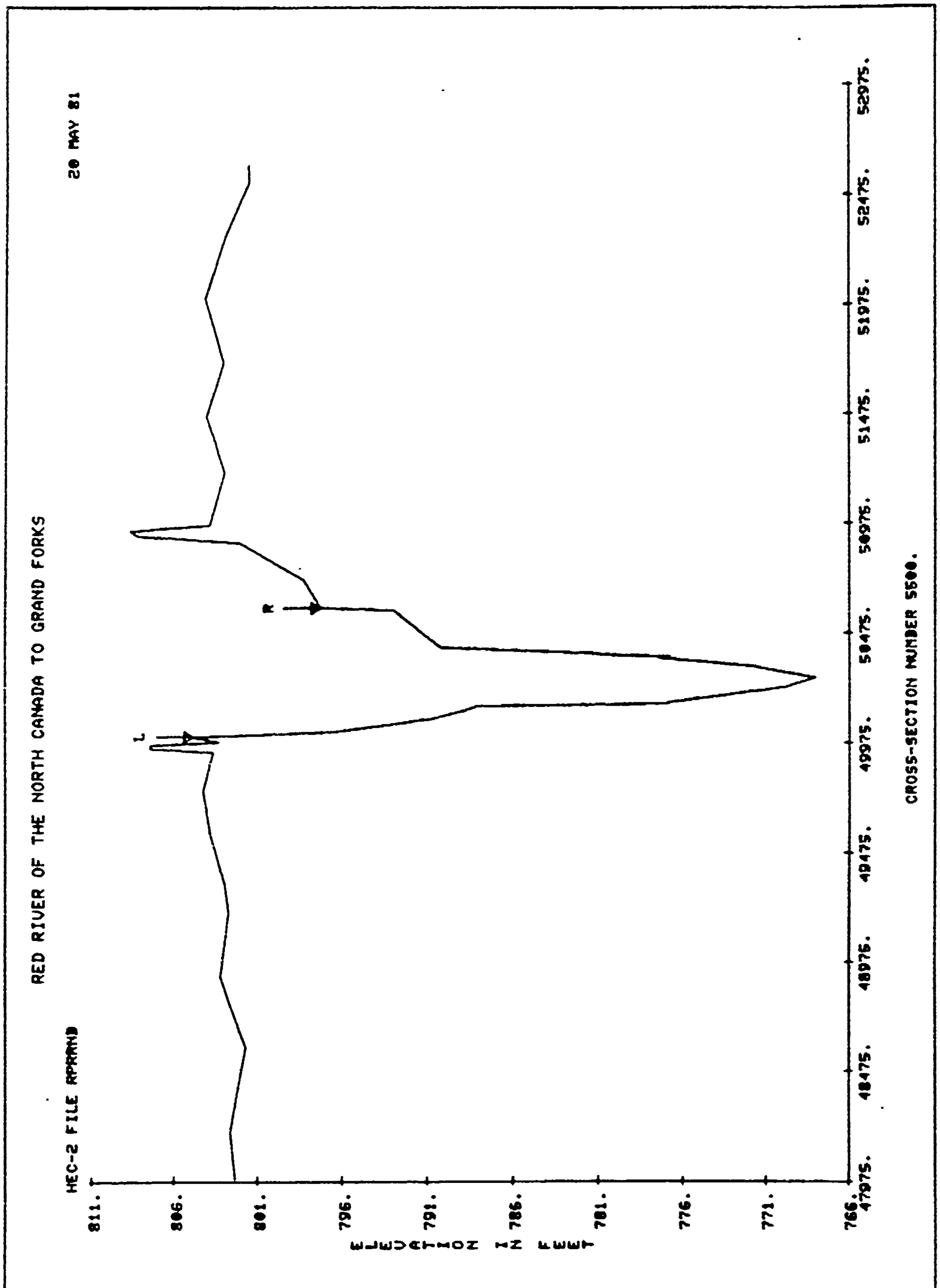

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ELEVATION IN FEET
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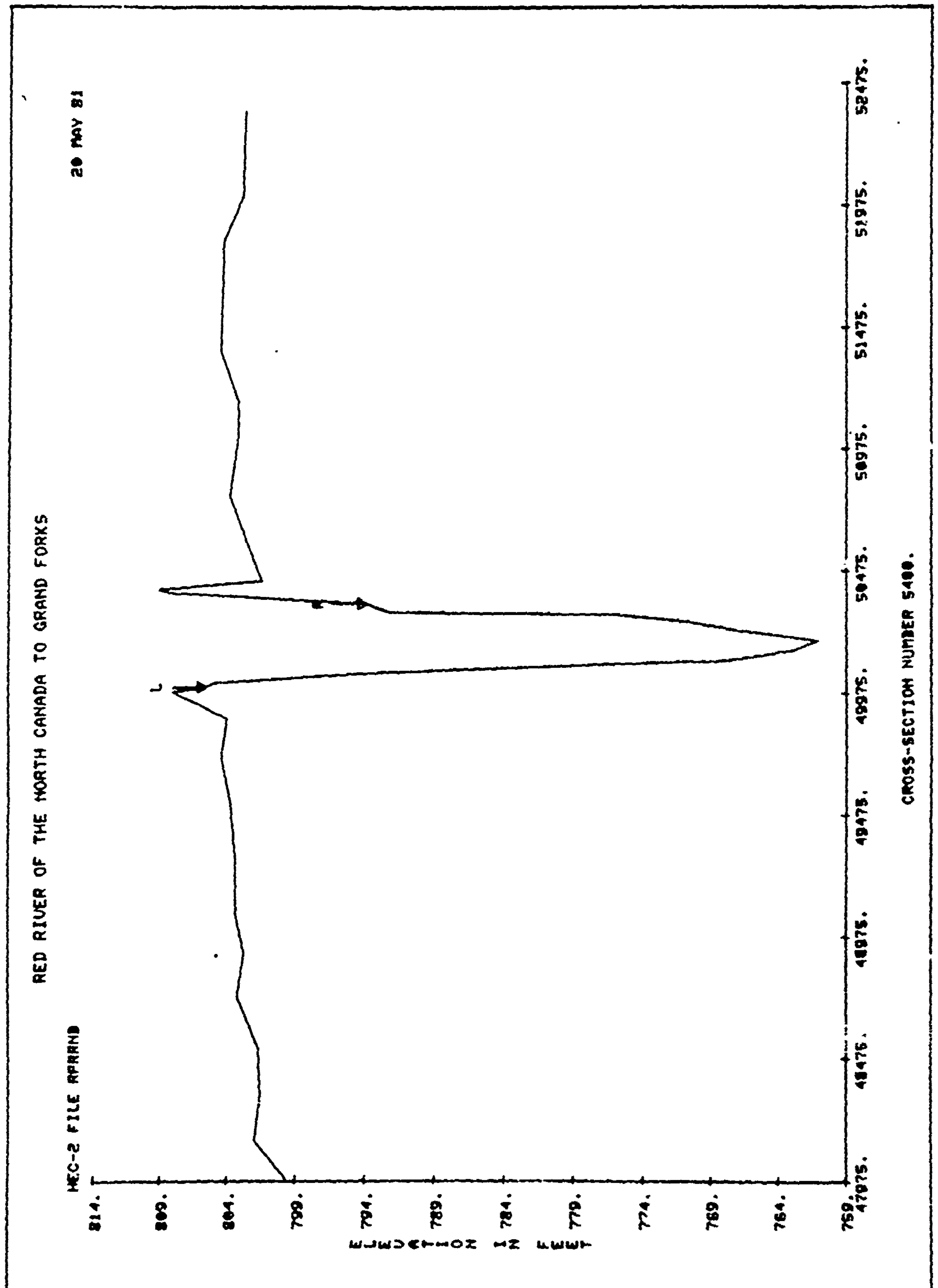

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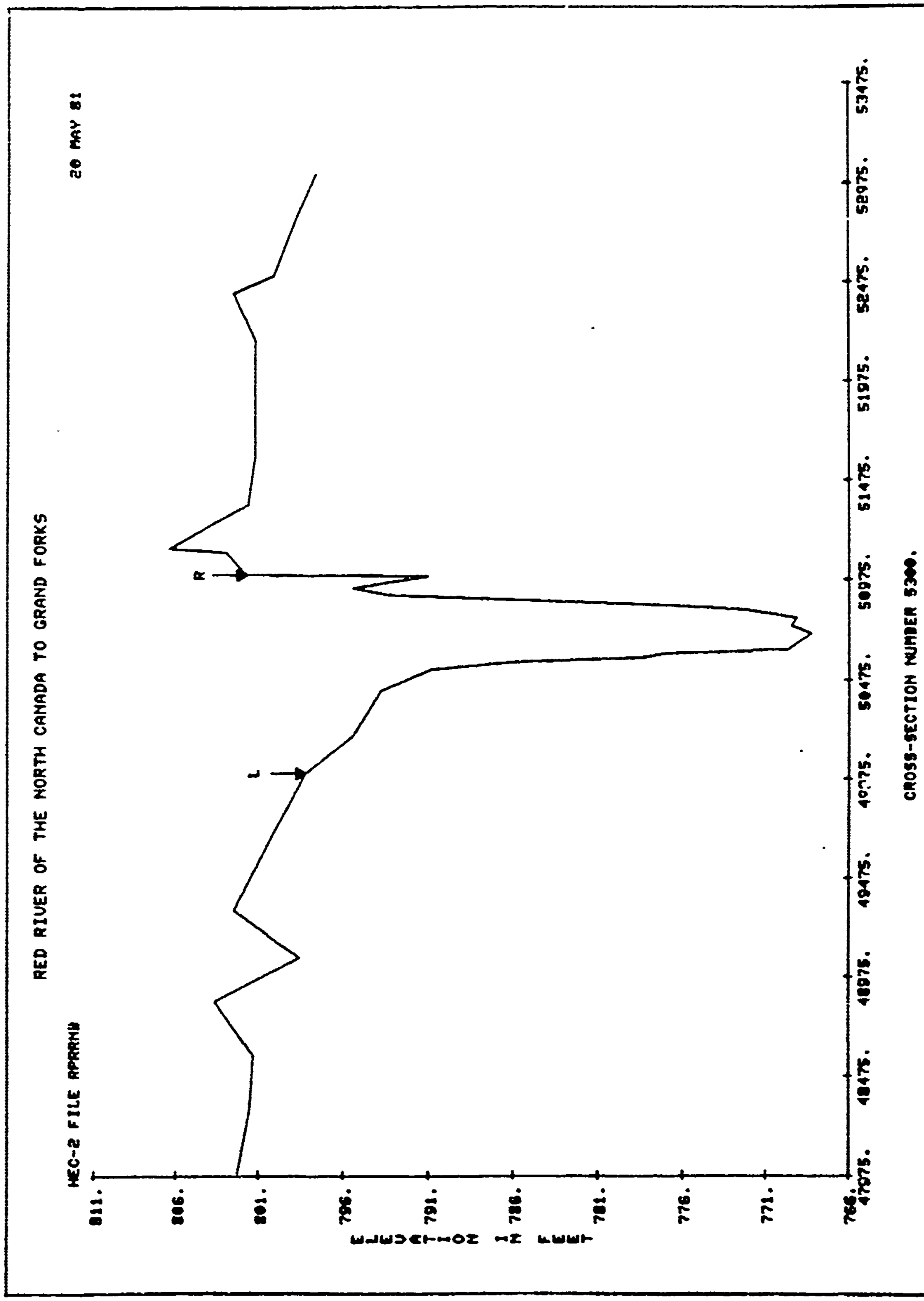

RED RIVER OF THE NORTH CANADA TO GRAND FORKS
20 MAY 81
HEC-2 FILE RPRRNW
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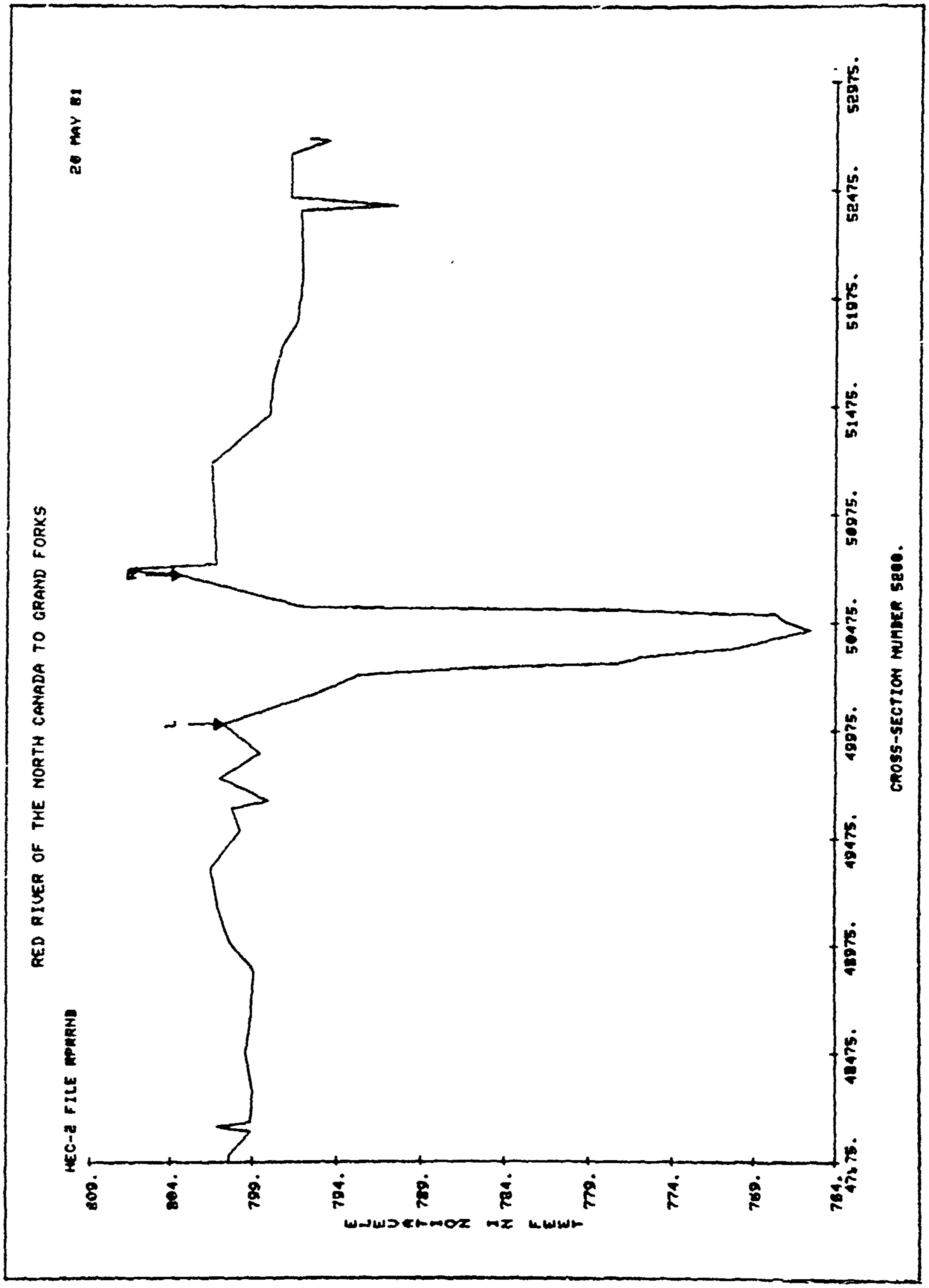

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ELEVATION IN FEET
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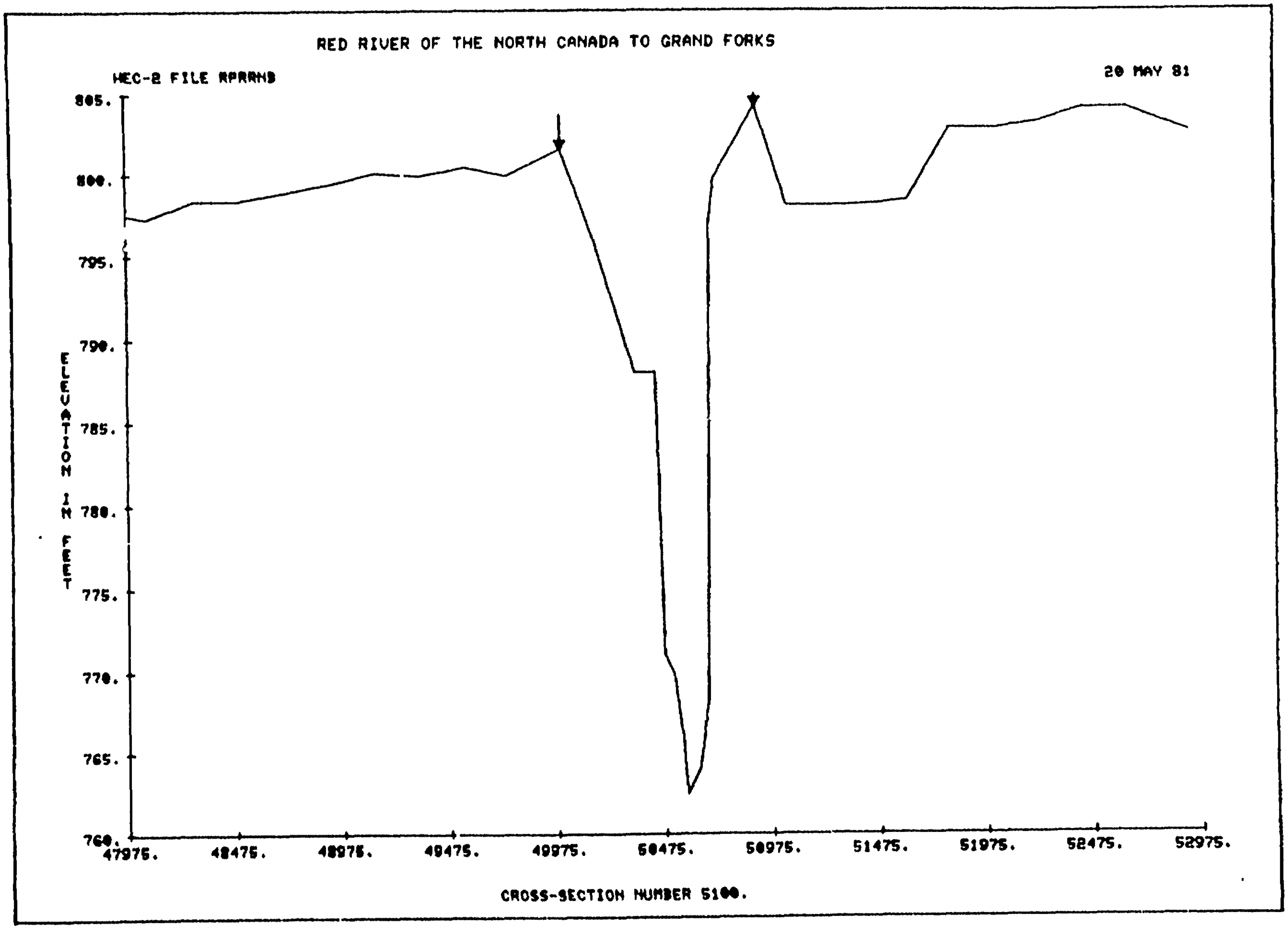
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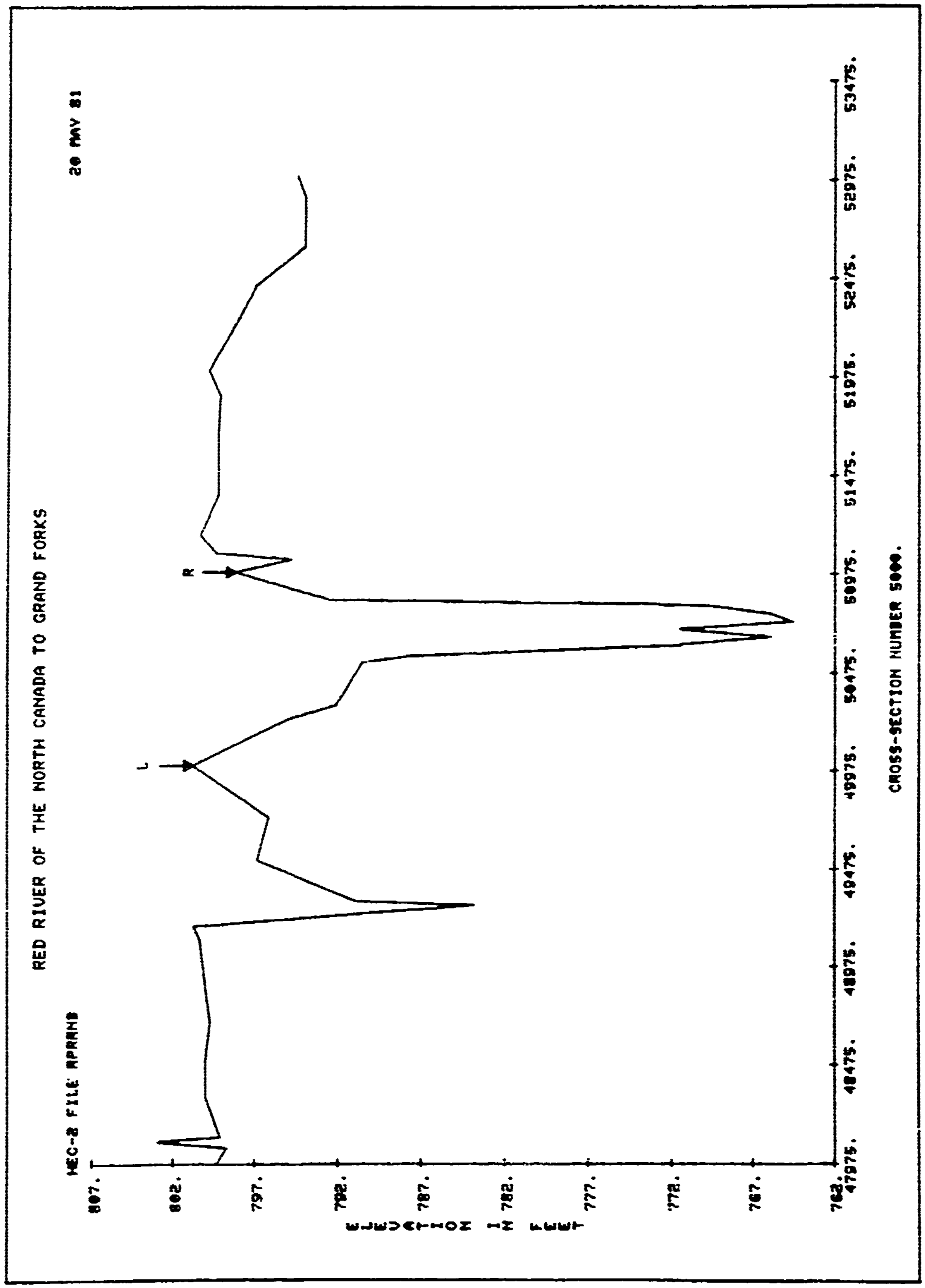
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
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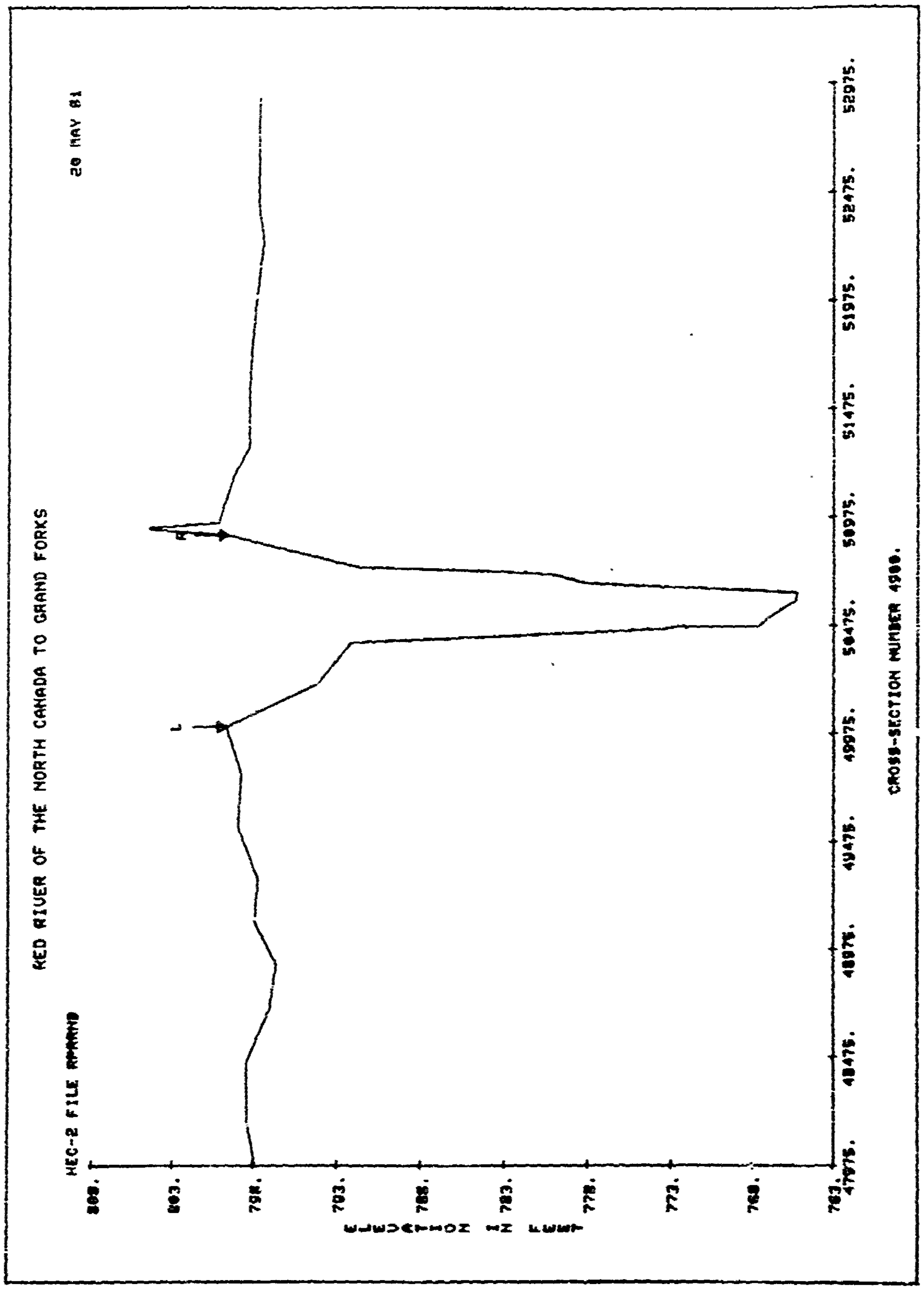

RED RIVER OF THE NORTH CANADA TO GRAND FORKS
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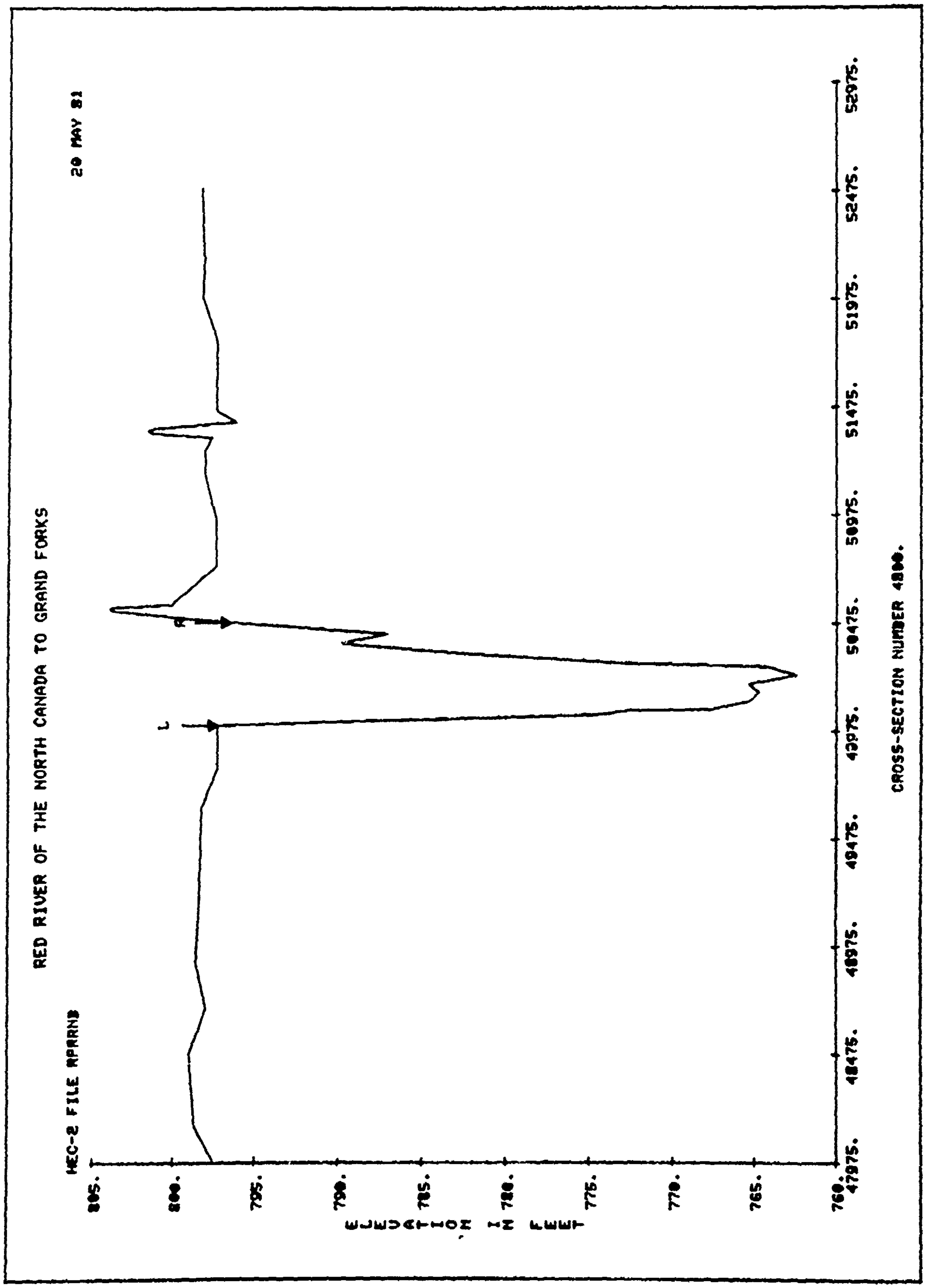

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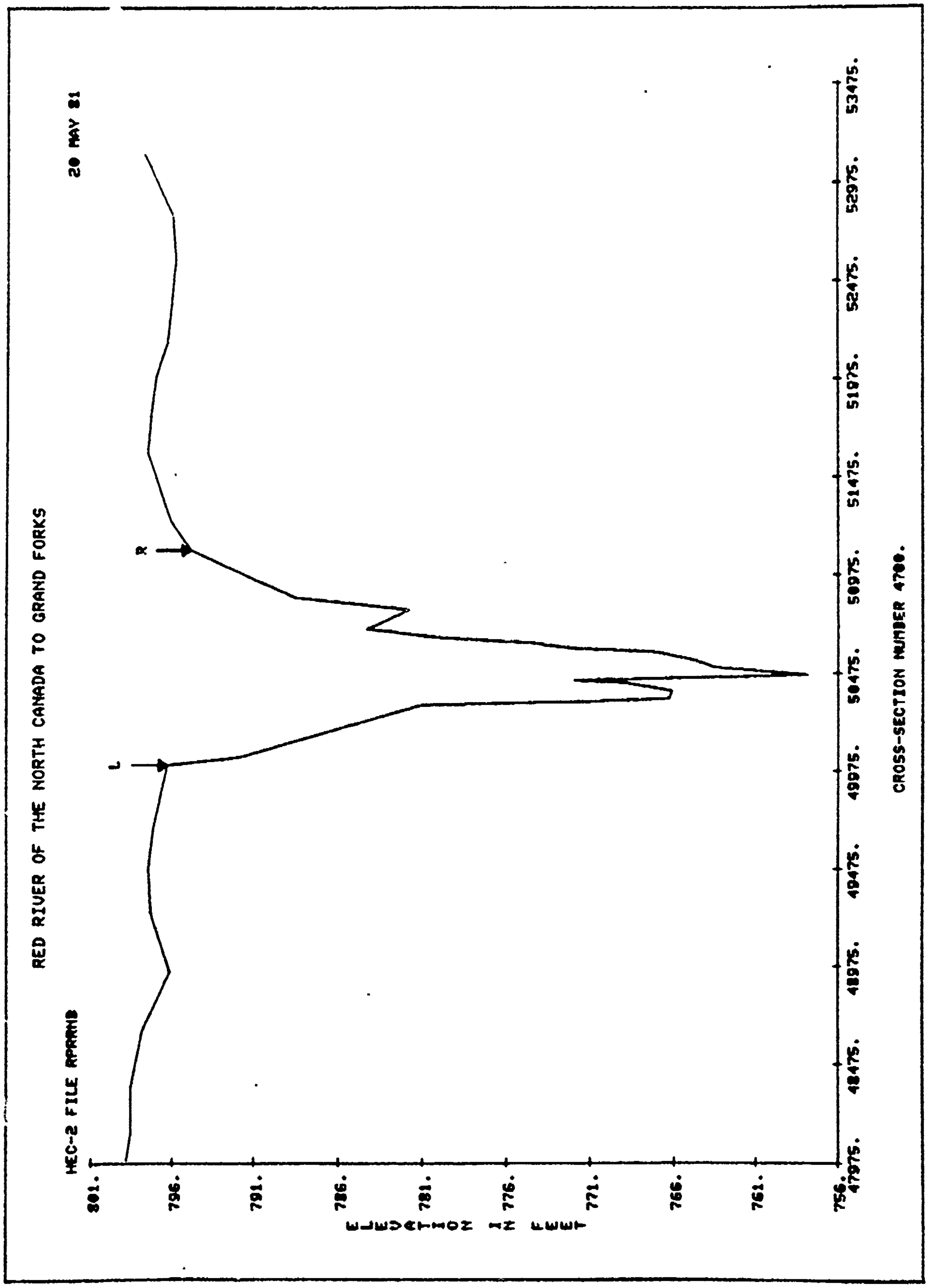

HEC-2 FILE RPRMB
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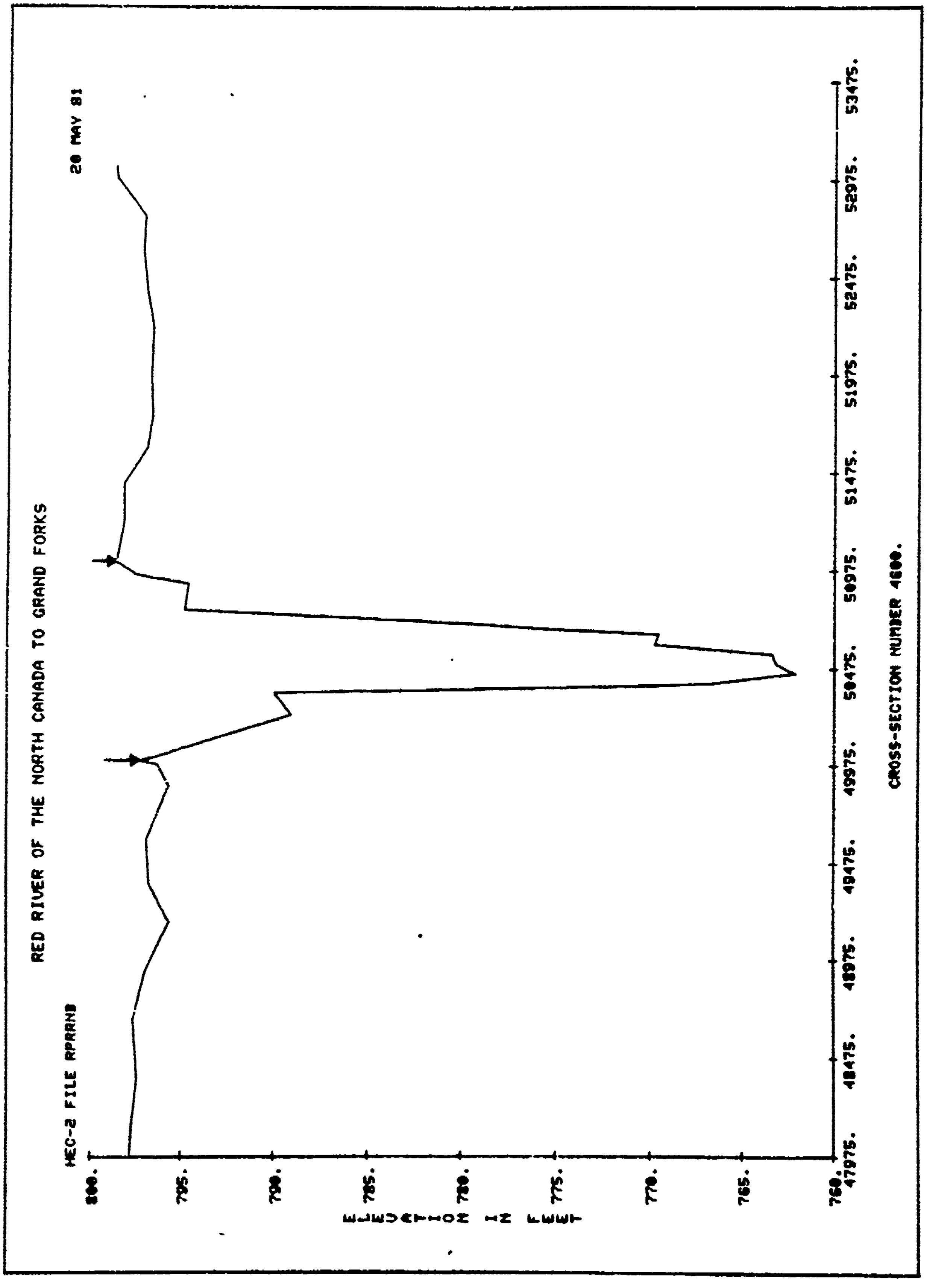

RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRNB
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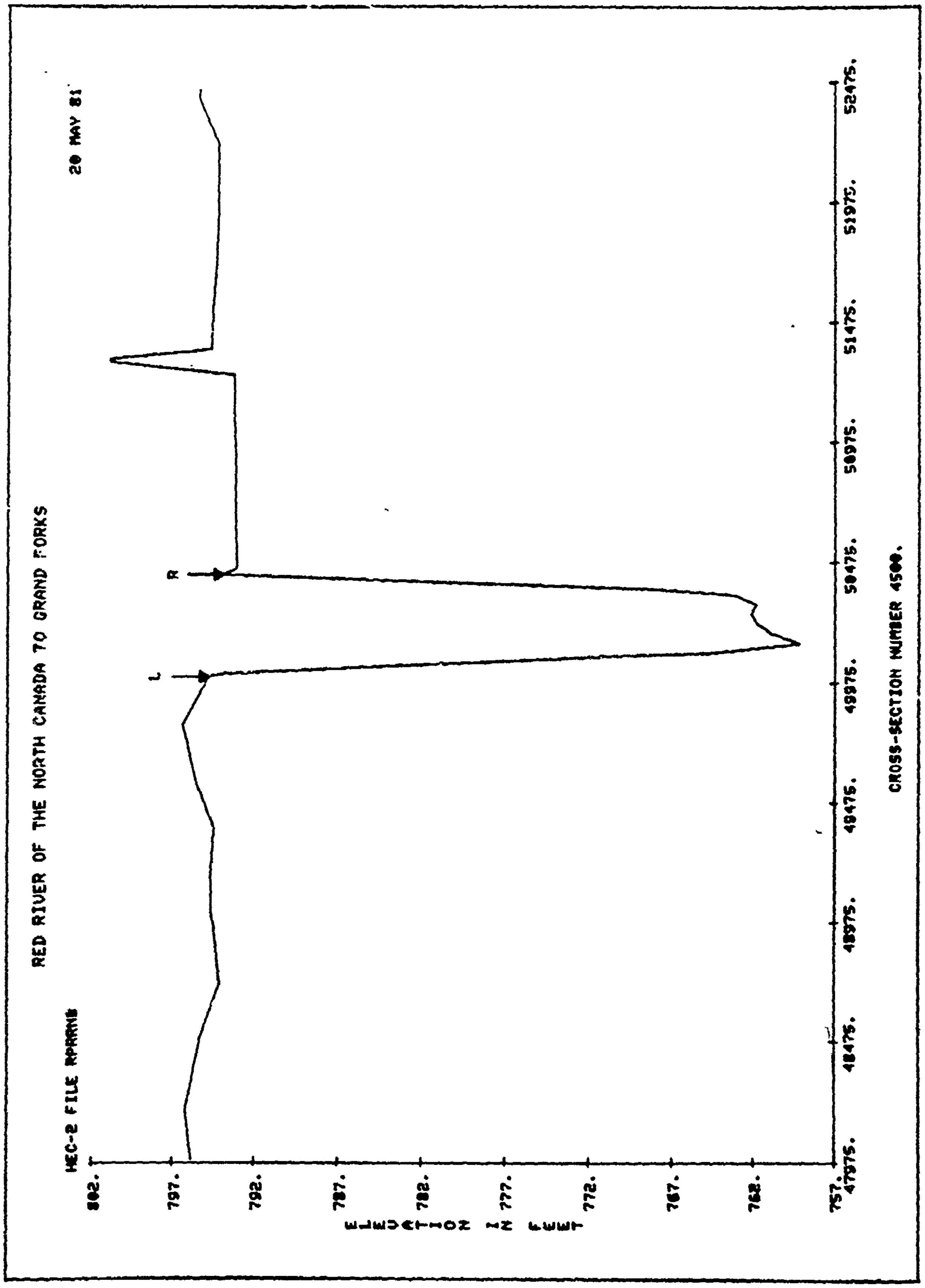
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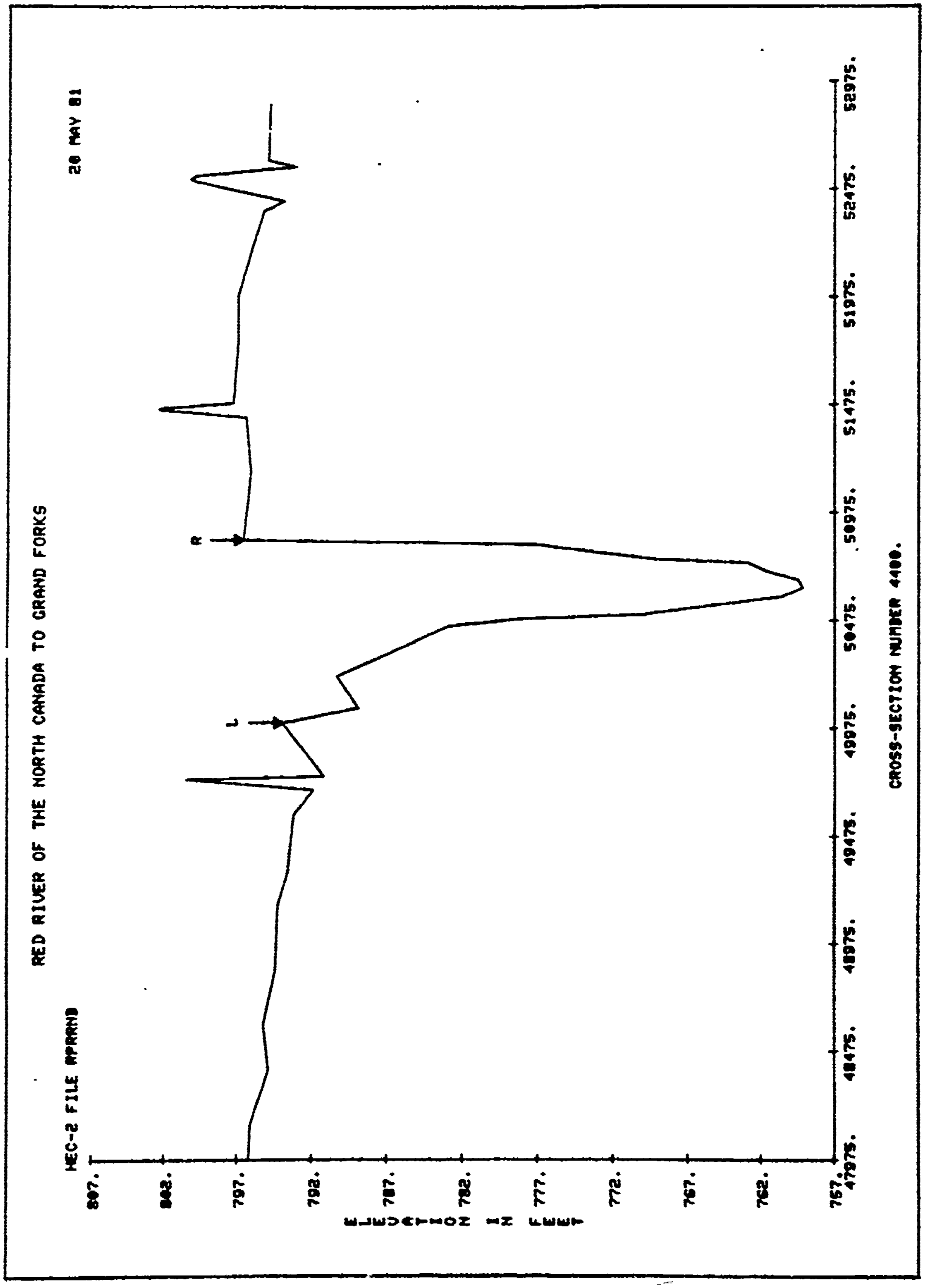
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ELEVATION IN FEET
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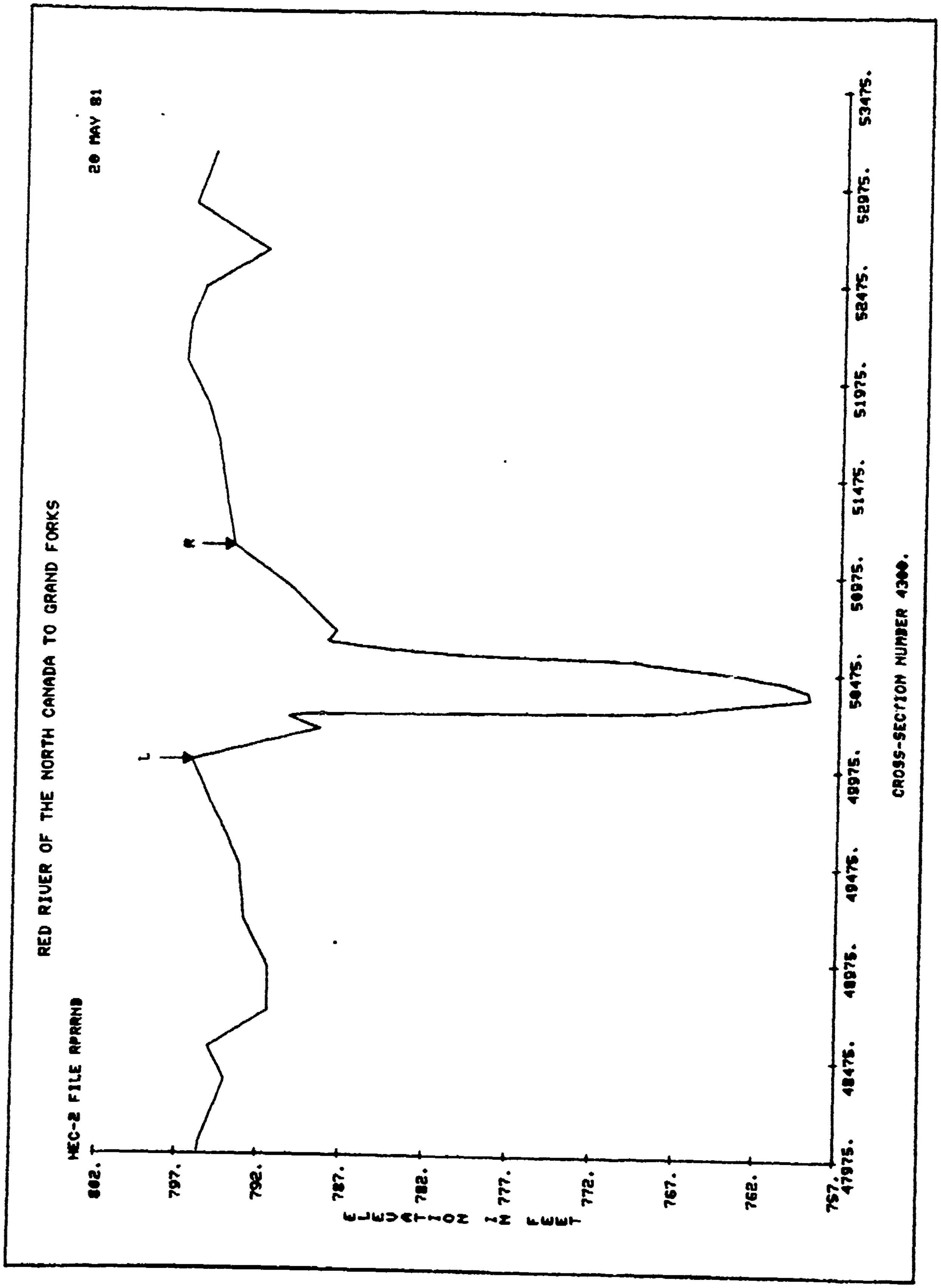
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RED RIVER OF THE NORTH CANADA TO GRAND FORKS
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ELEVATION IN FEET
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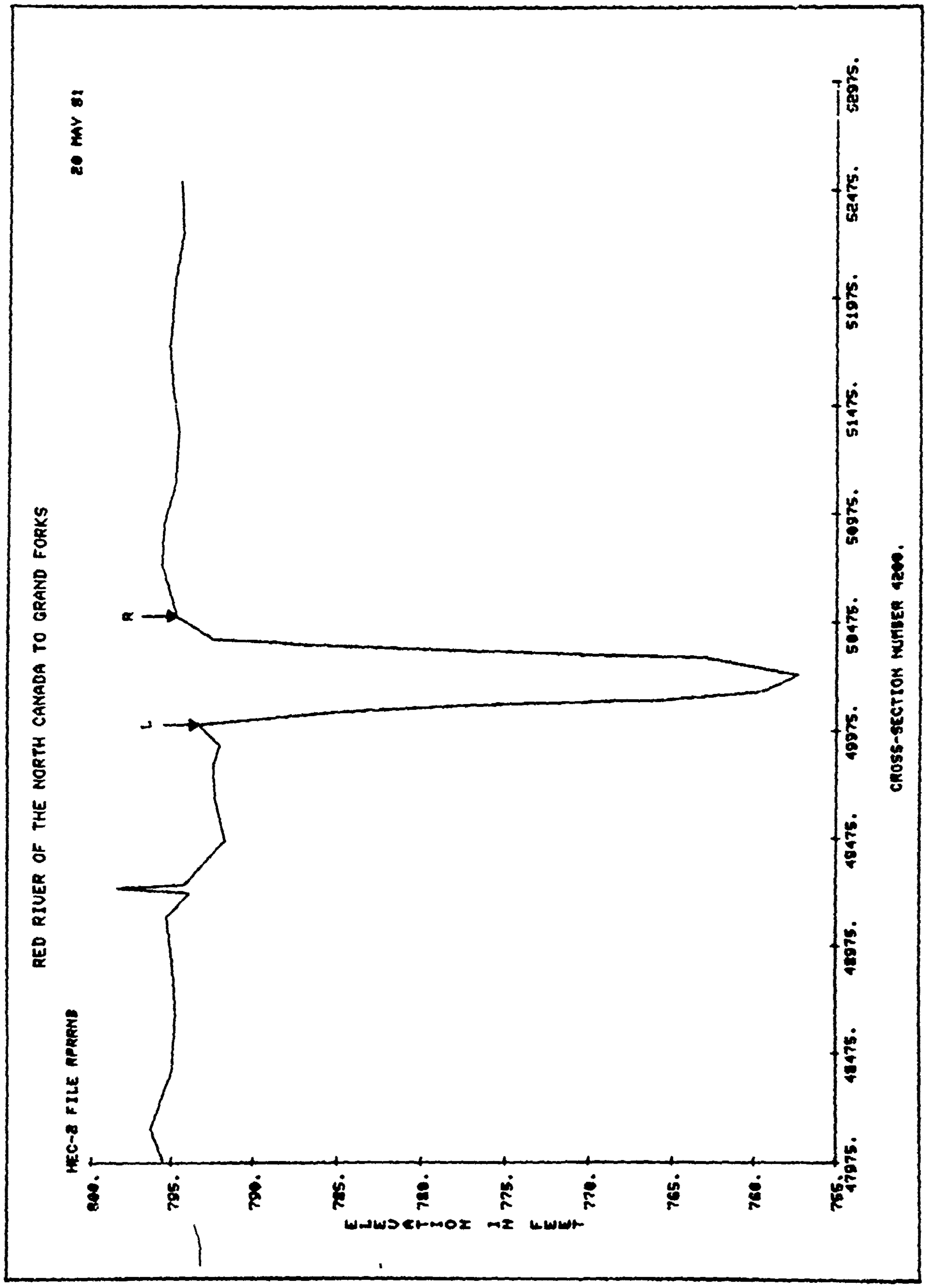
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ELEVATION IN FEET
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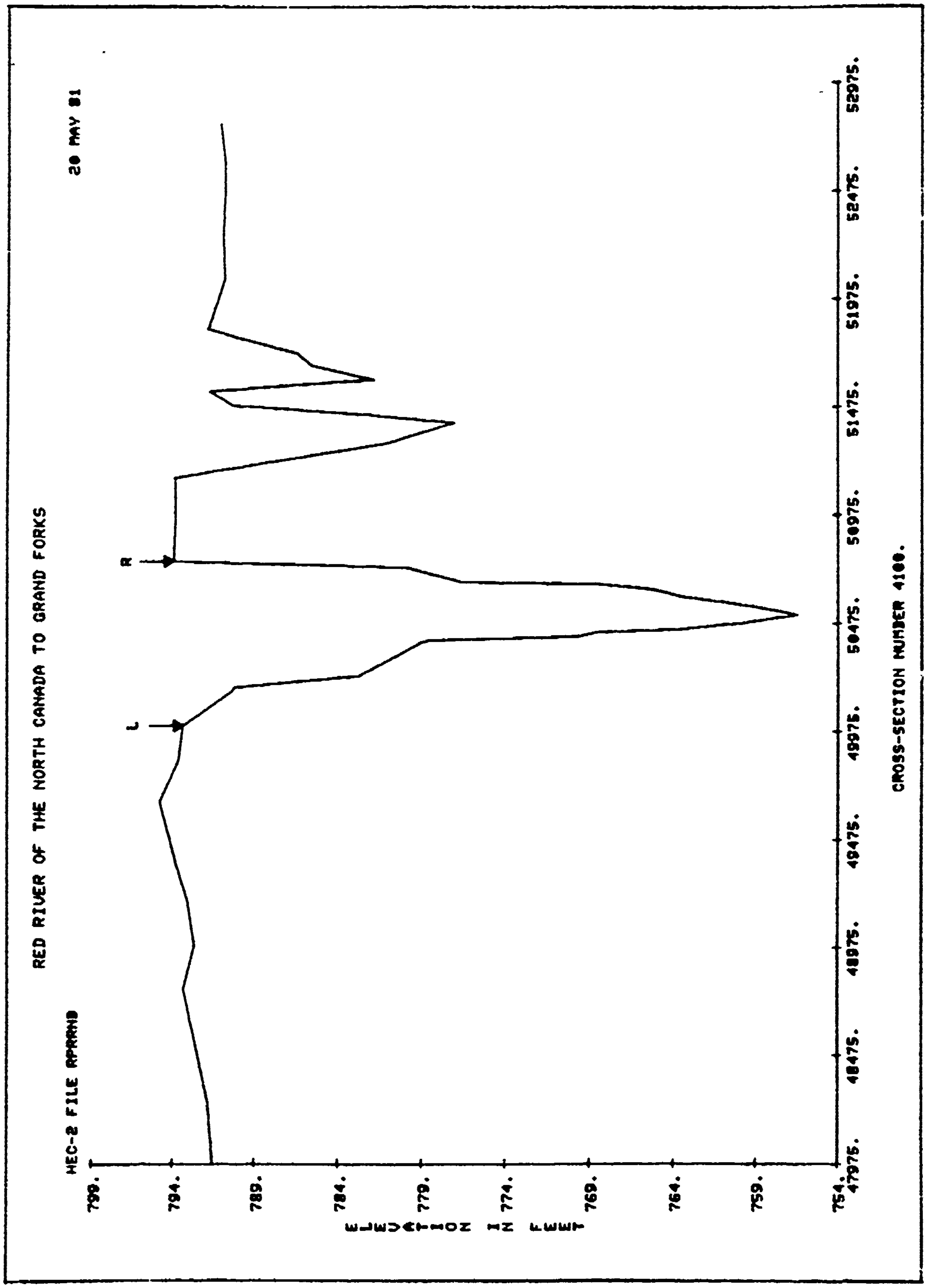

HEC-2 FILE RPRRND
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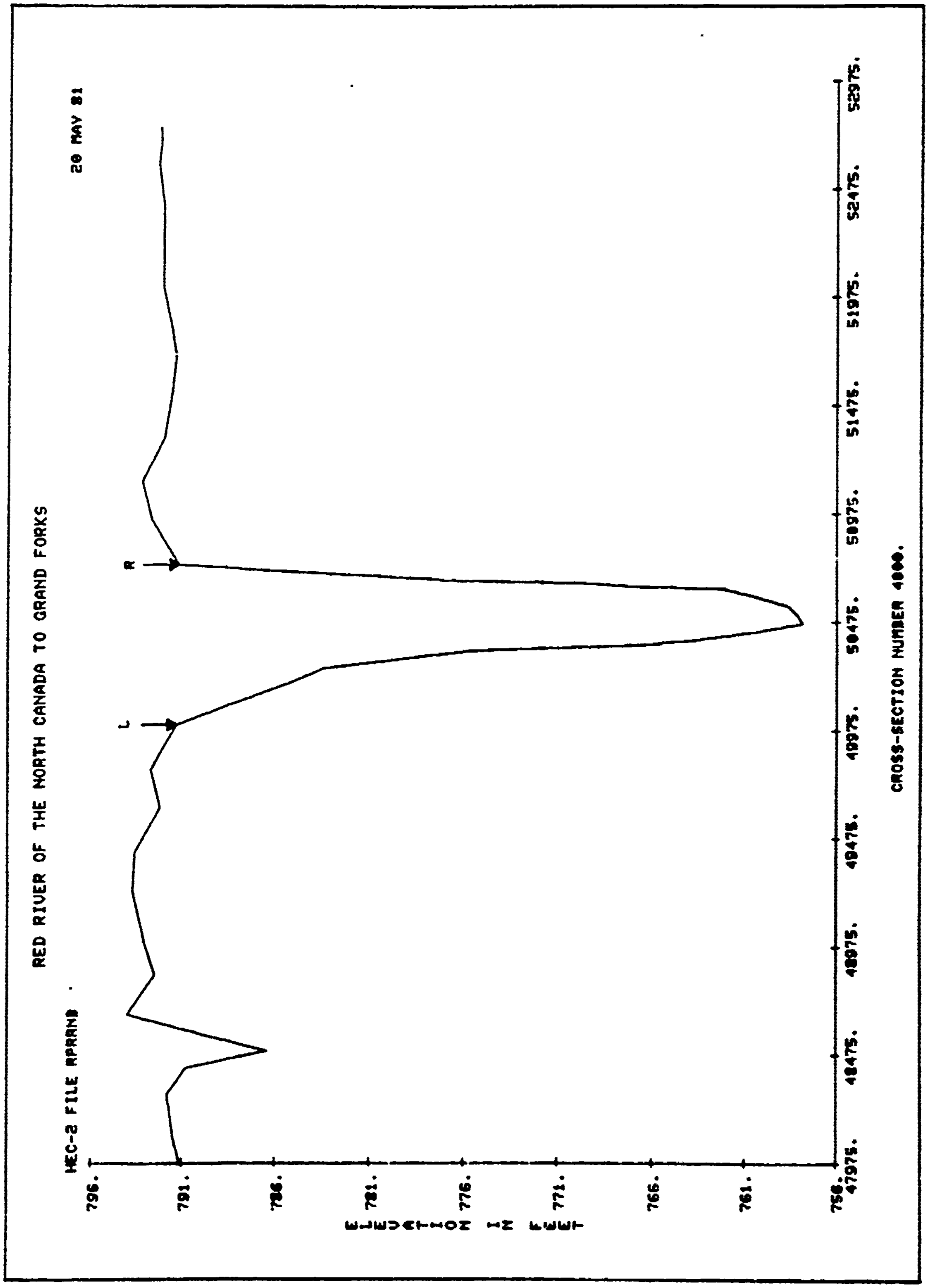
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ELEVATION IN FEET
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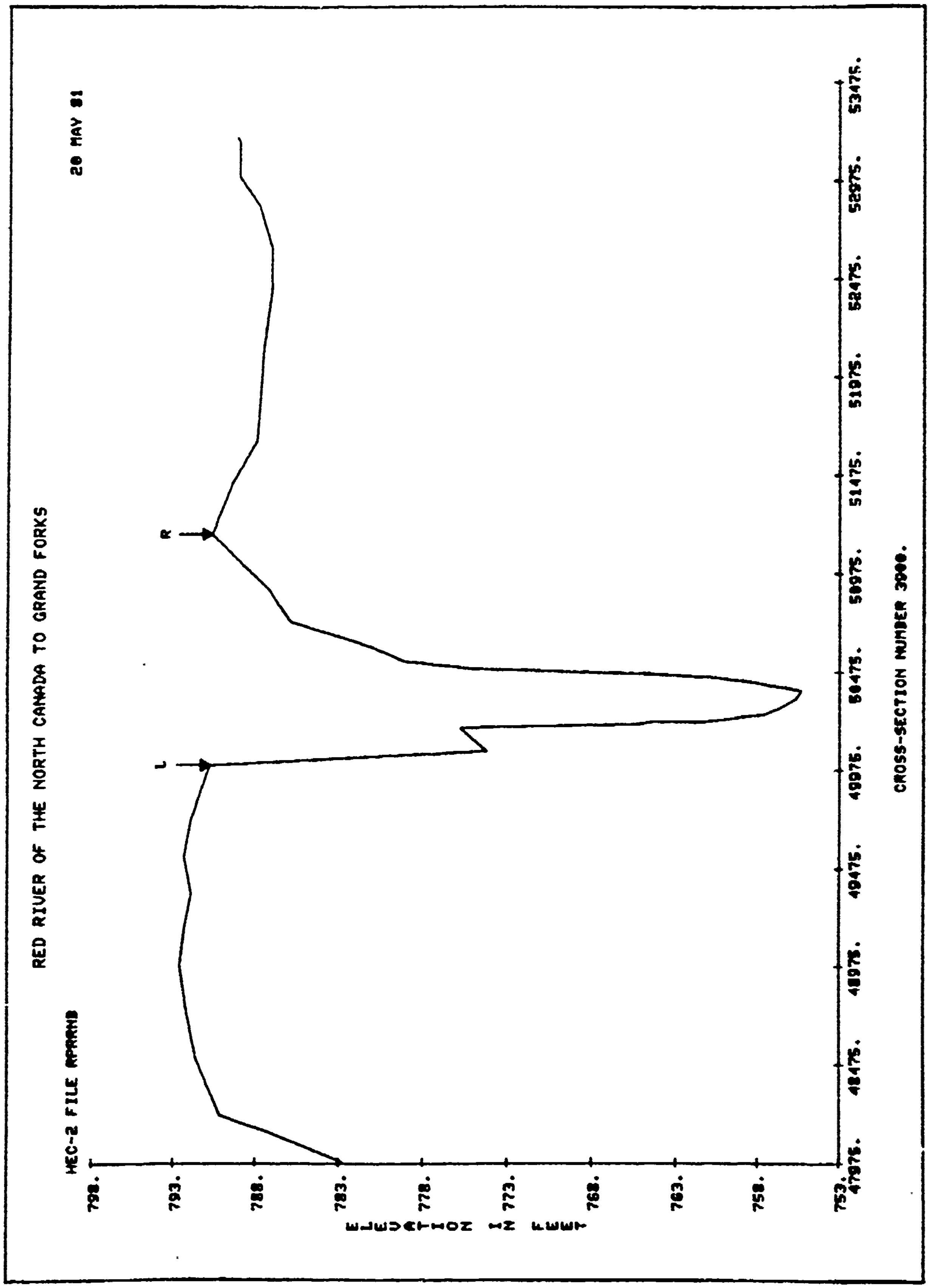
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HEC-2 FILE
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ELEVATION IN FEET
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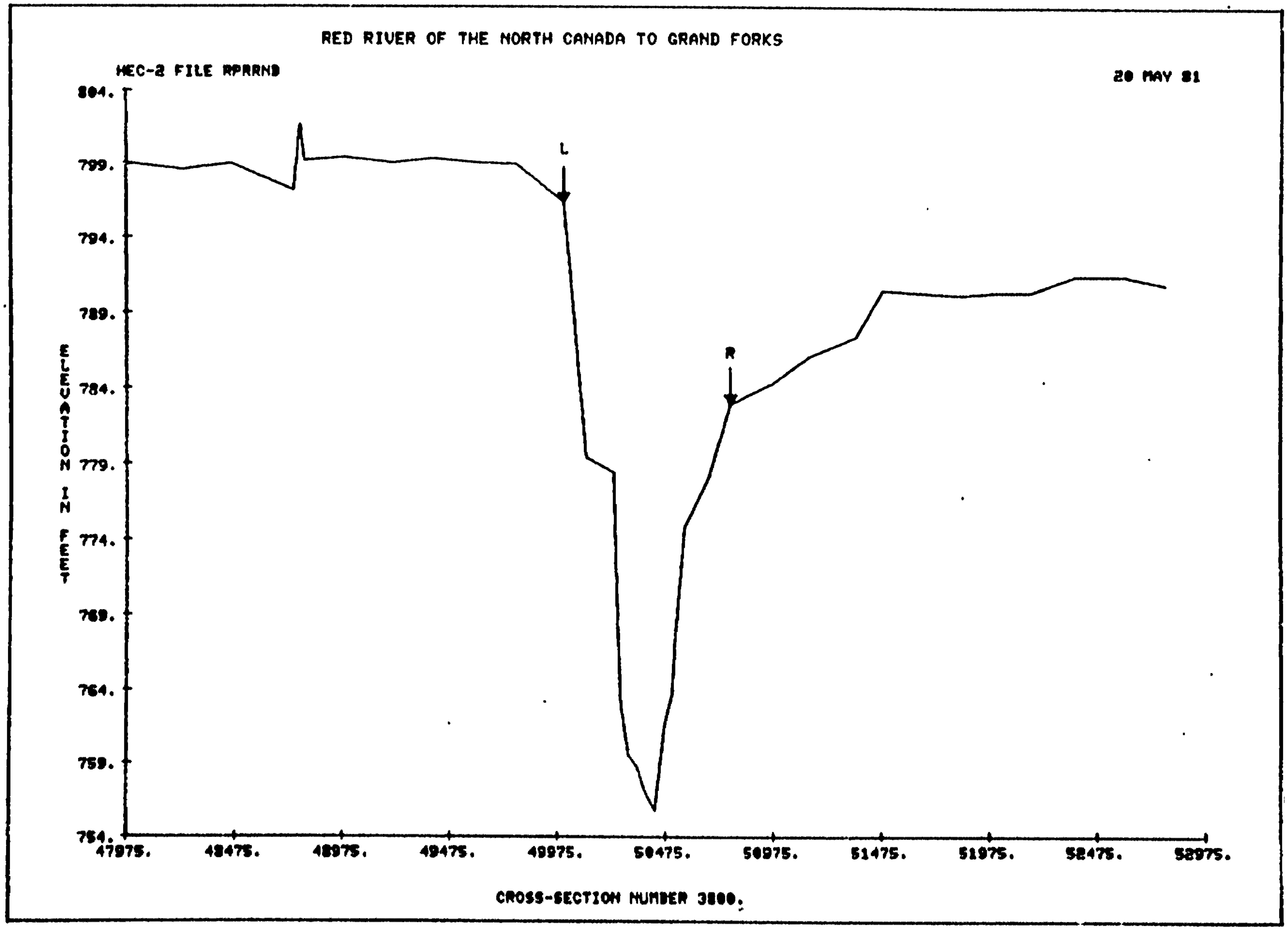
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ELEVATION IN FEET
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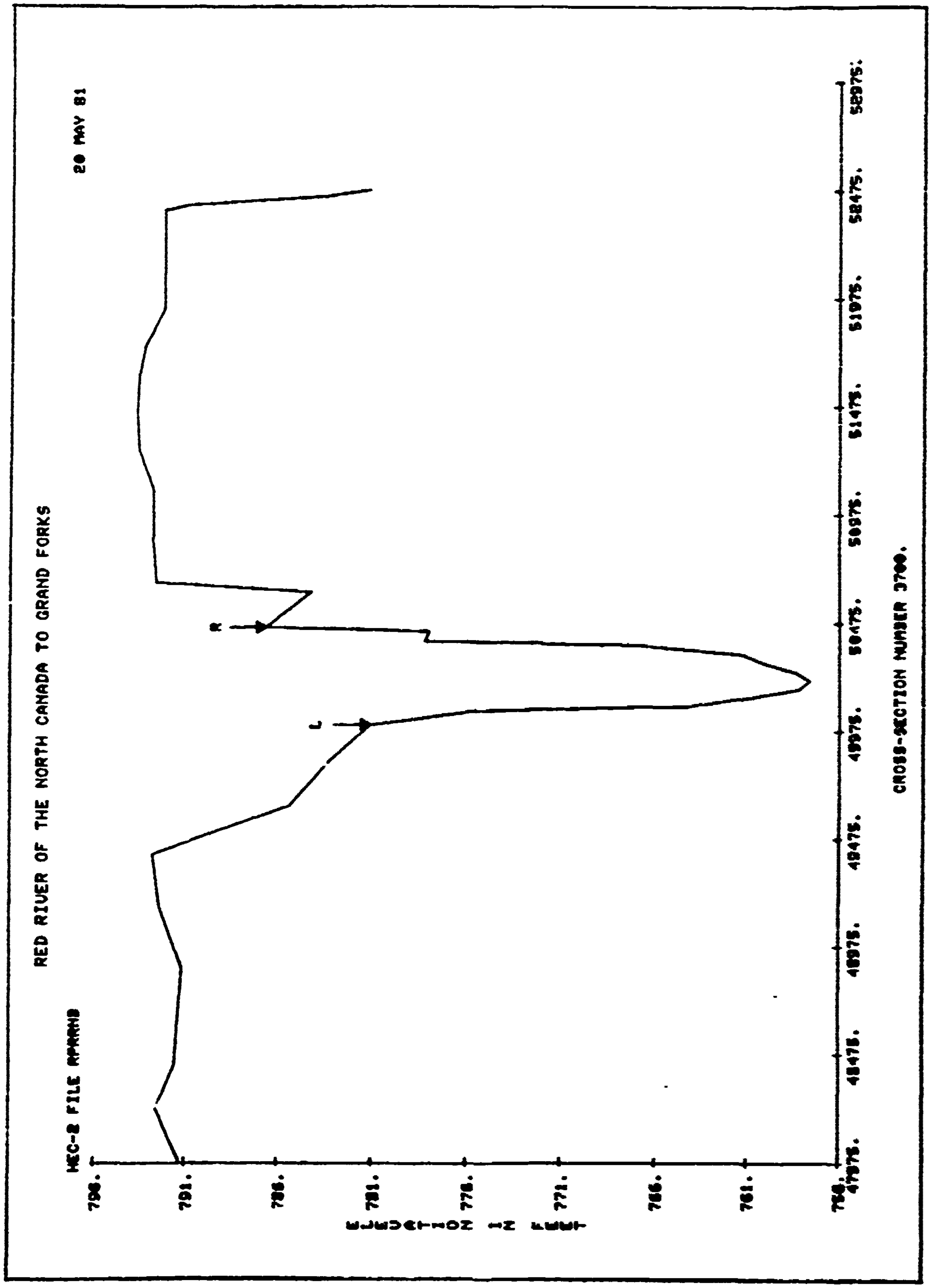
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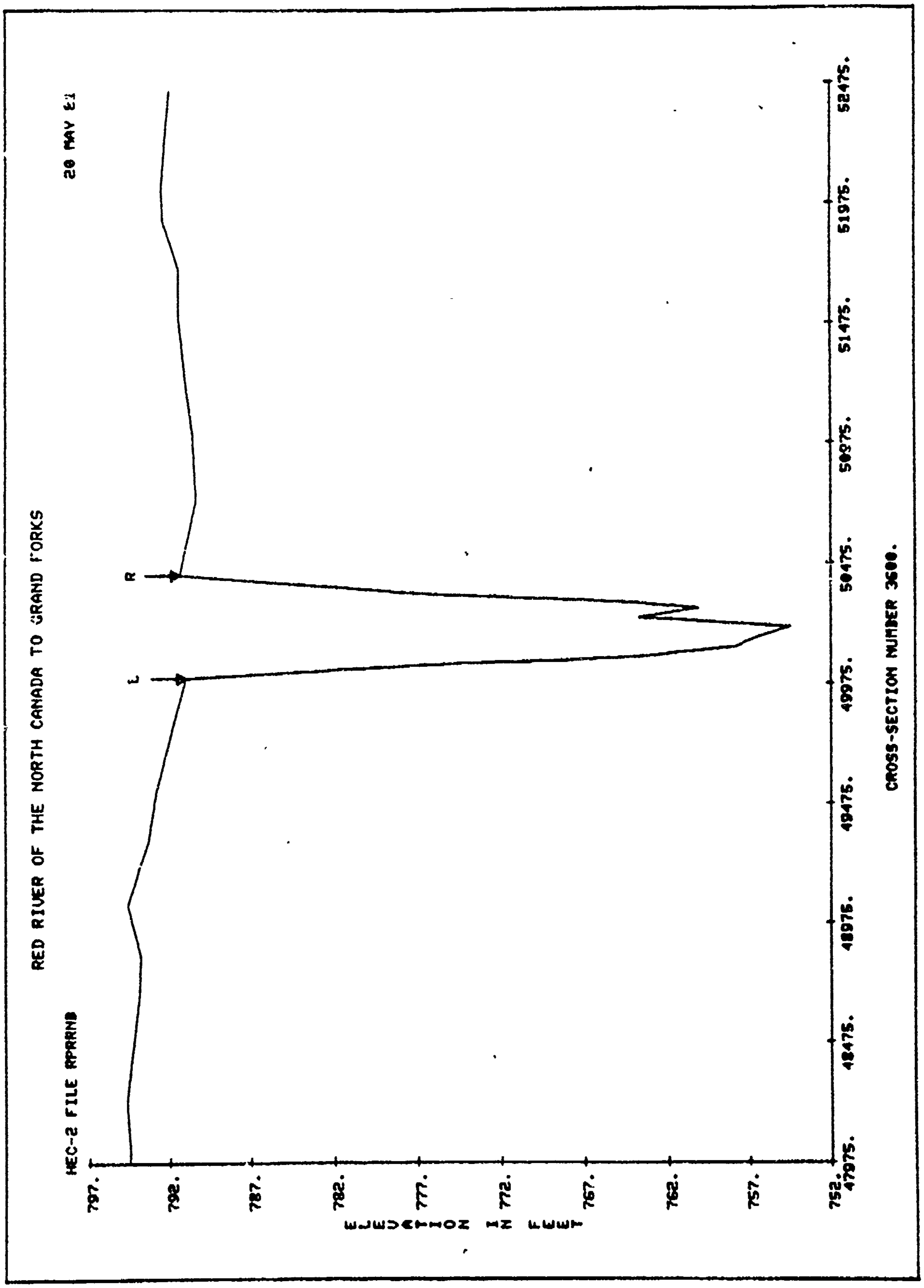
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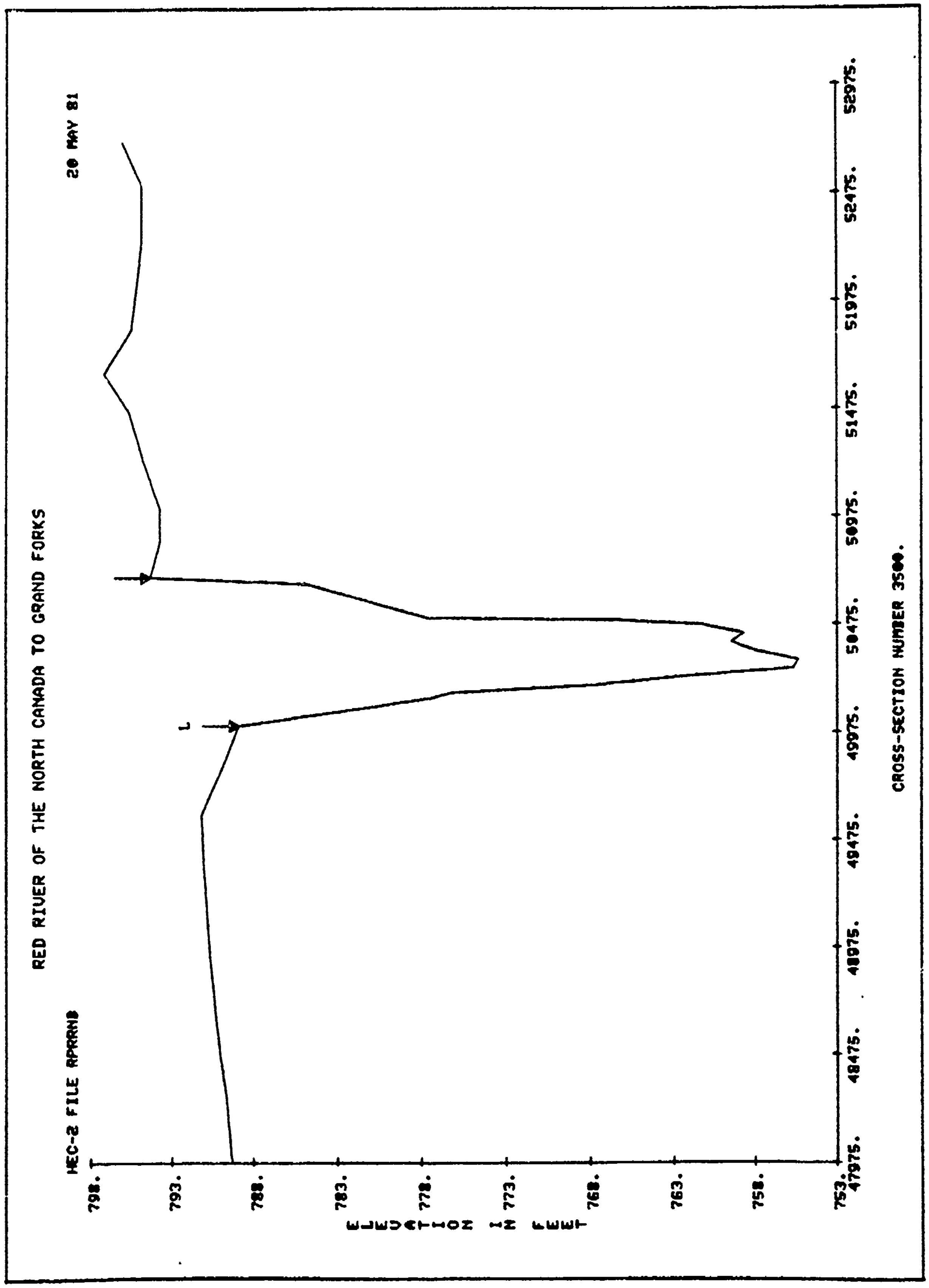
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
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ELEVATION IN FEET
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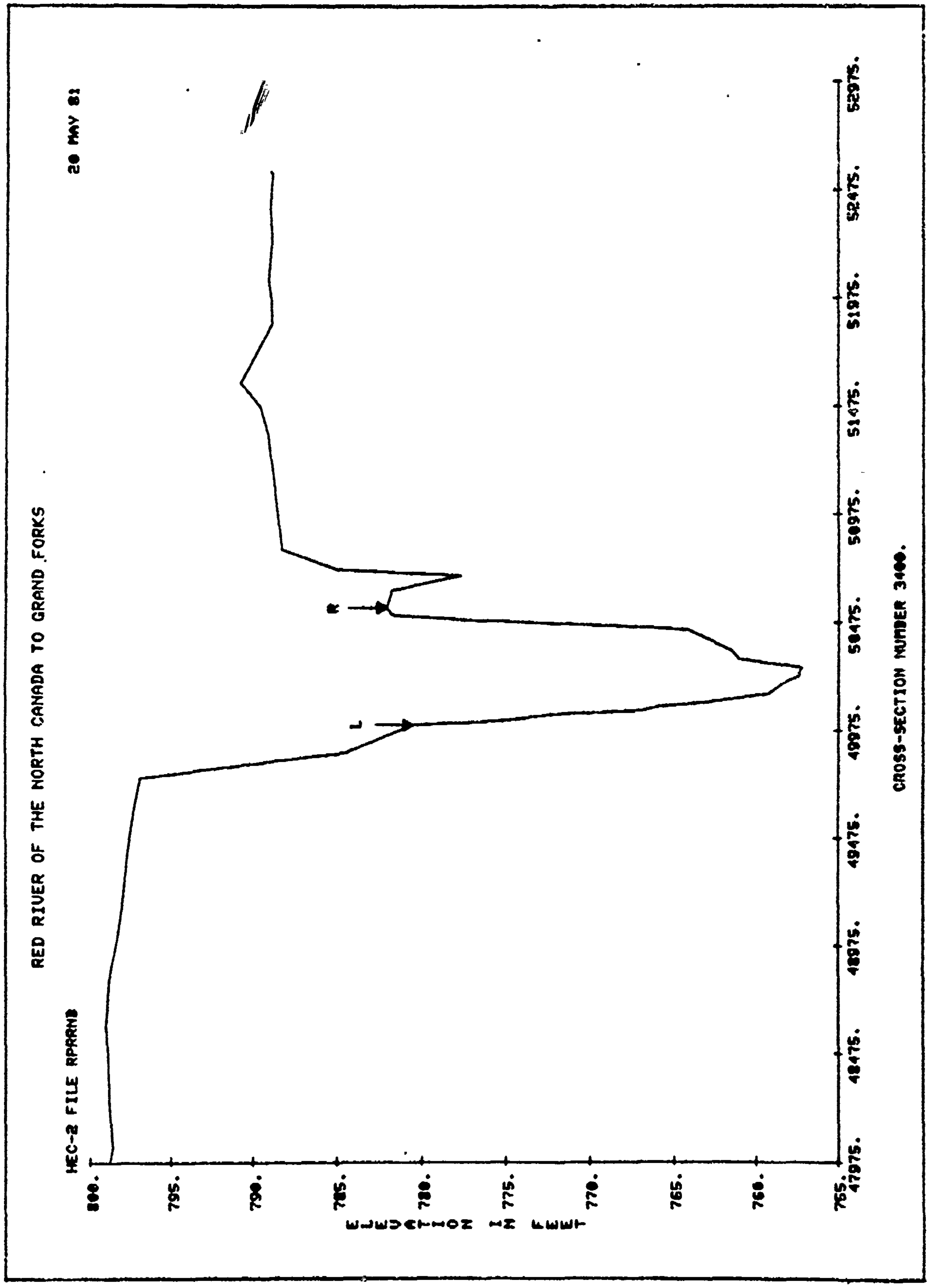
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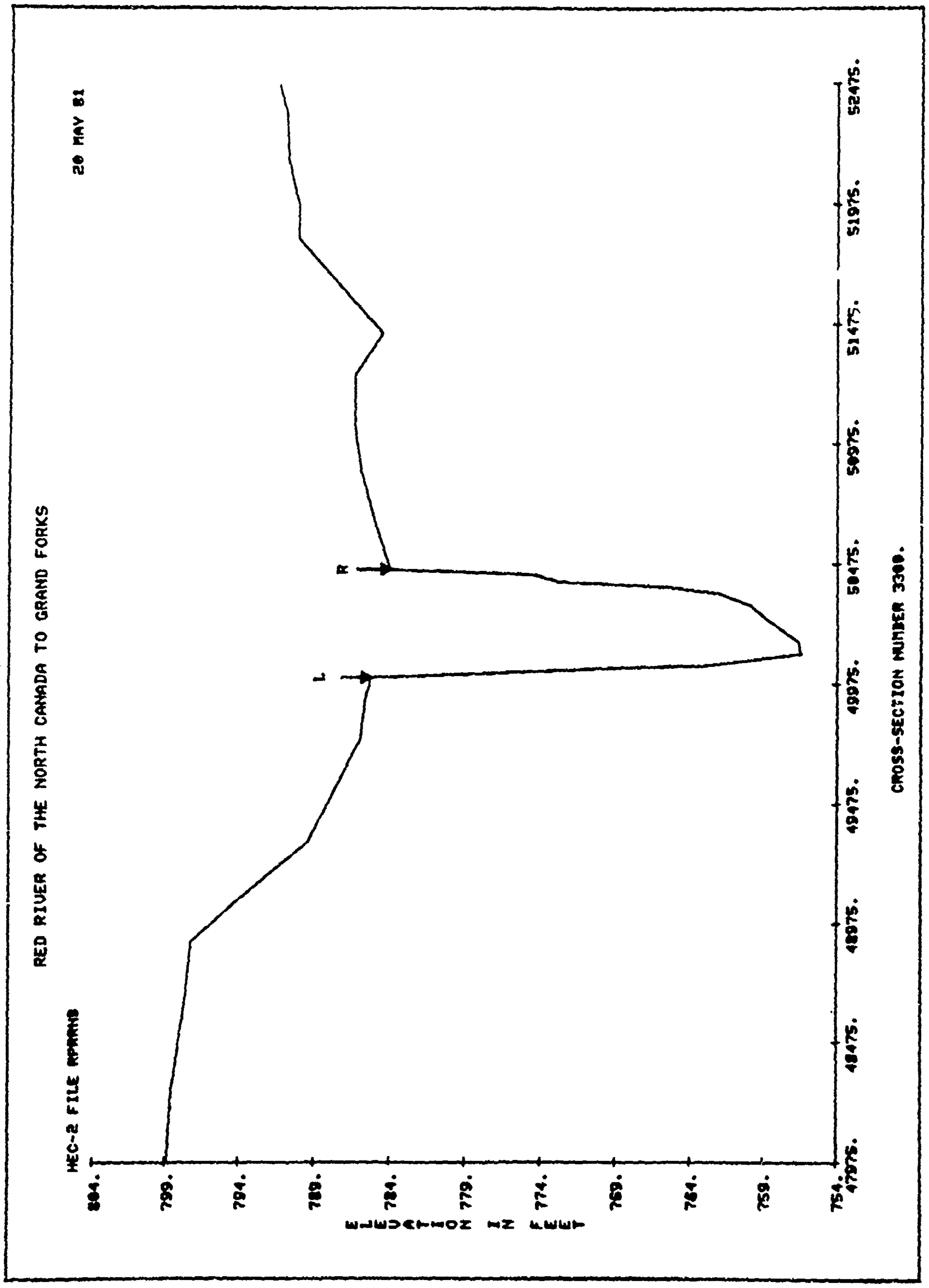

RED RIVER OF THE NORTH CANADA TO GRAND FORKS
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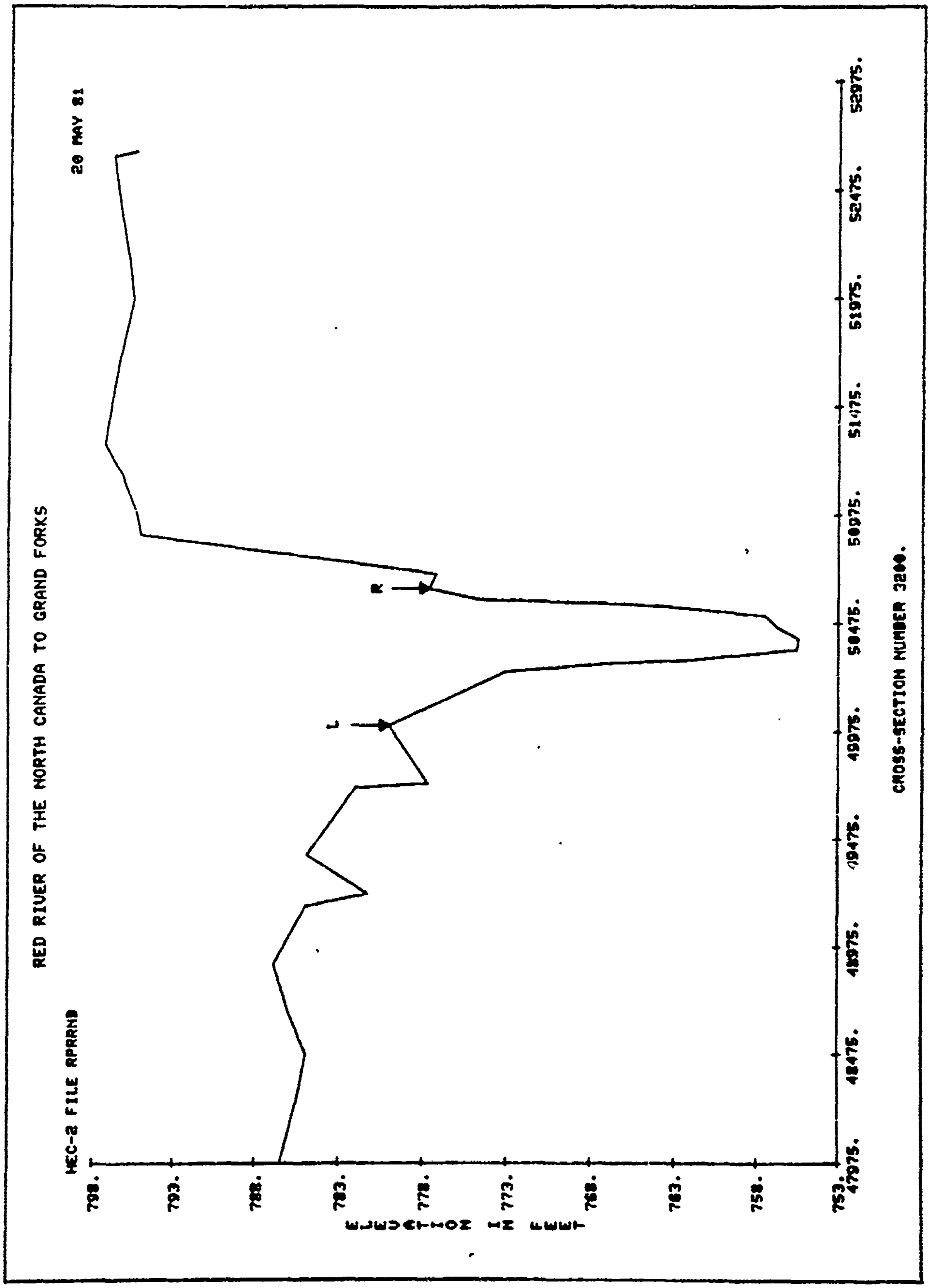
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
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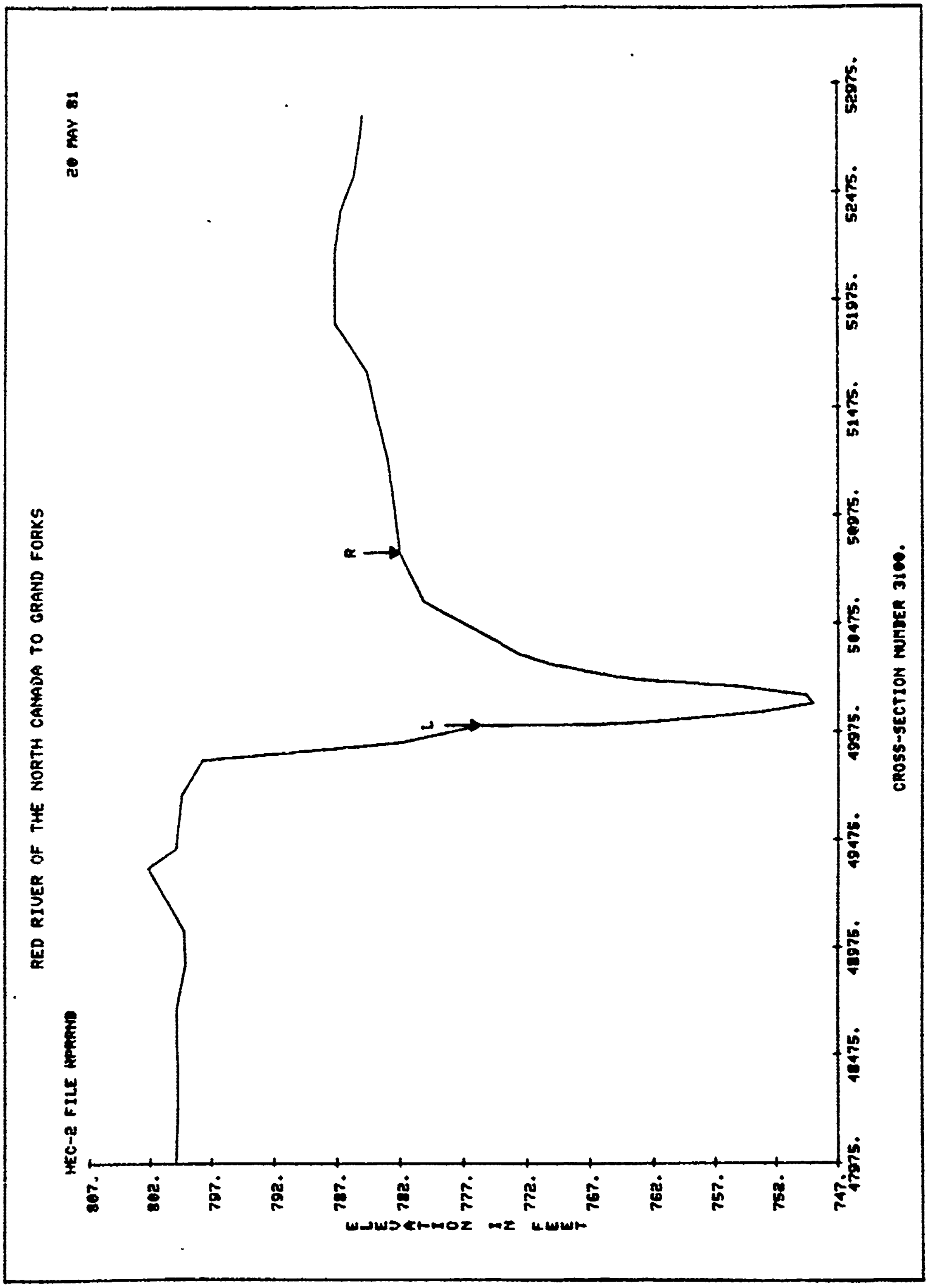

RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE NPRRND
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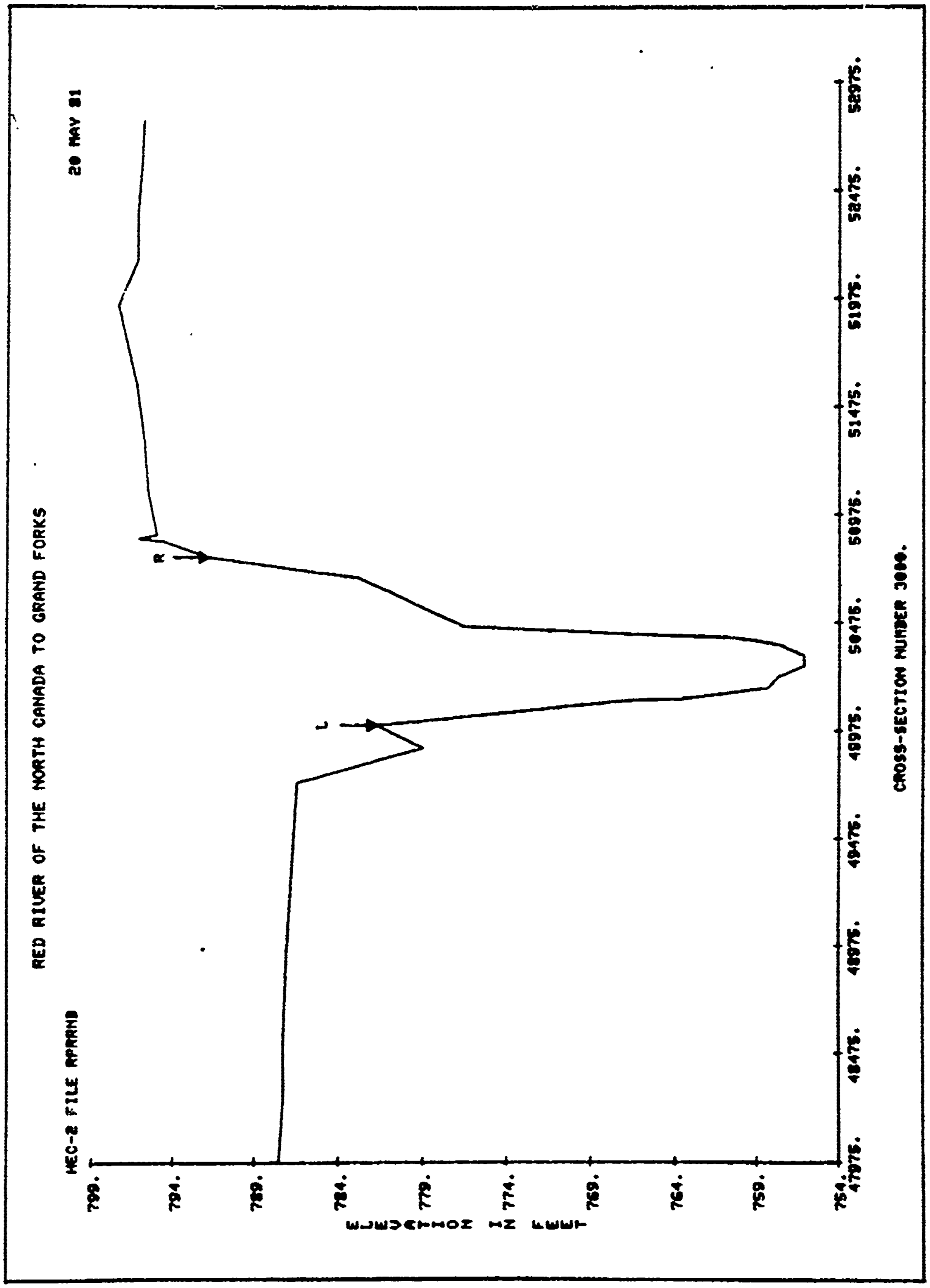
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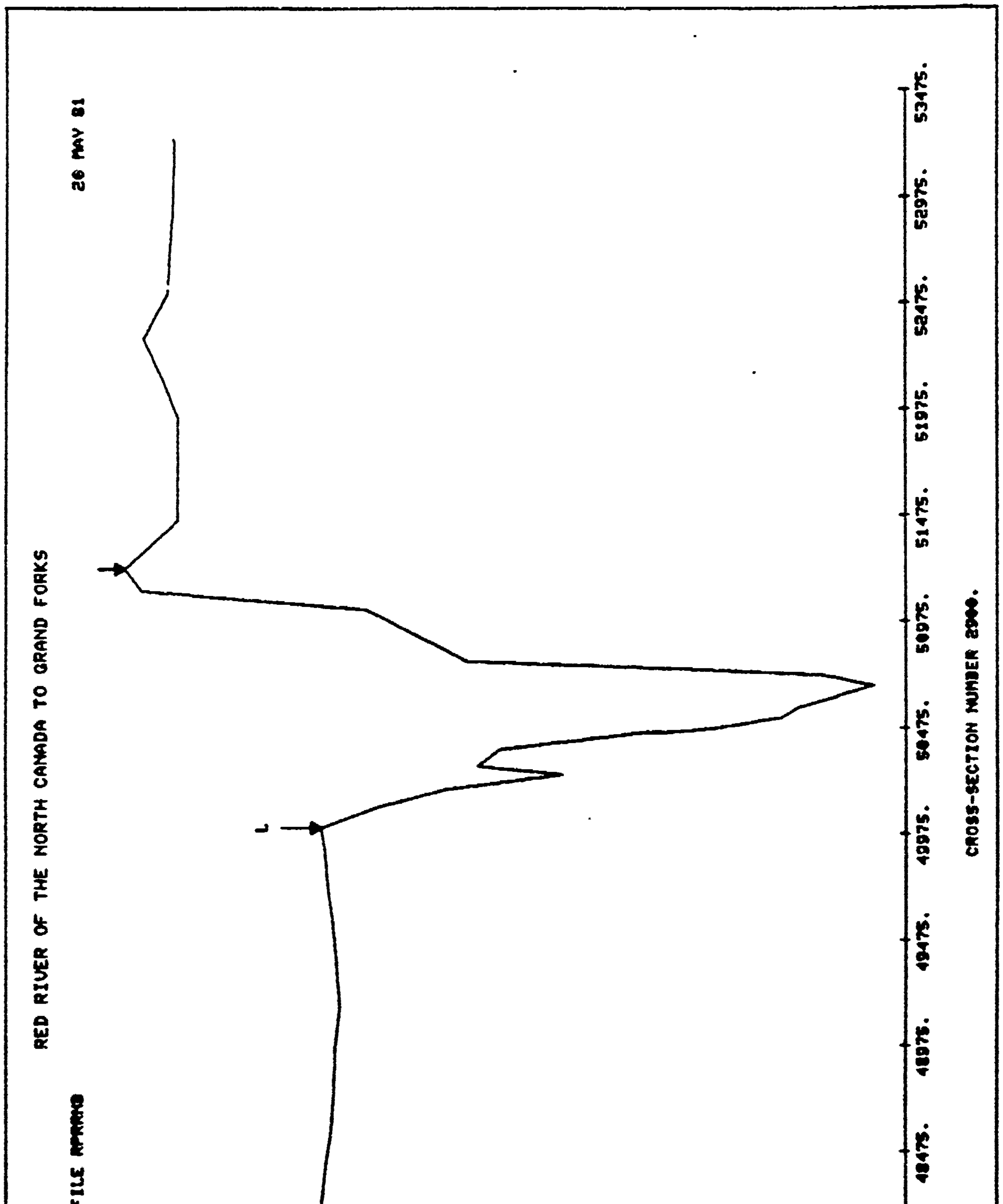
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20 MAY 81
HEC-2 FILE
ELEVATION IN FEET
801.
796.
791.
786.
781.
776.
771.
766.
761.
756.
751.
47975.
48475.
48975.
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50975.
51475.
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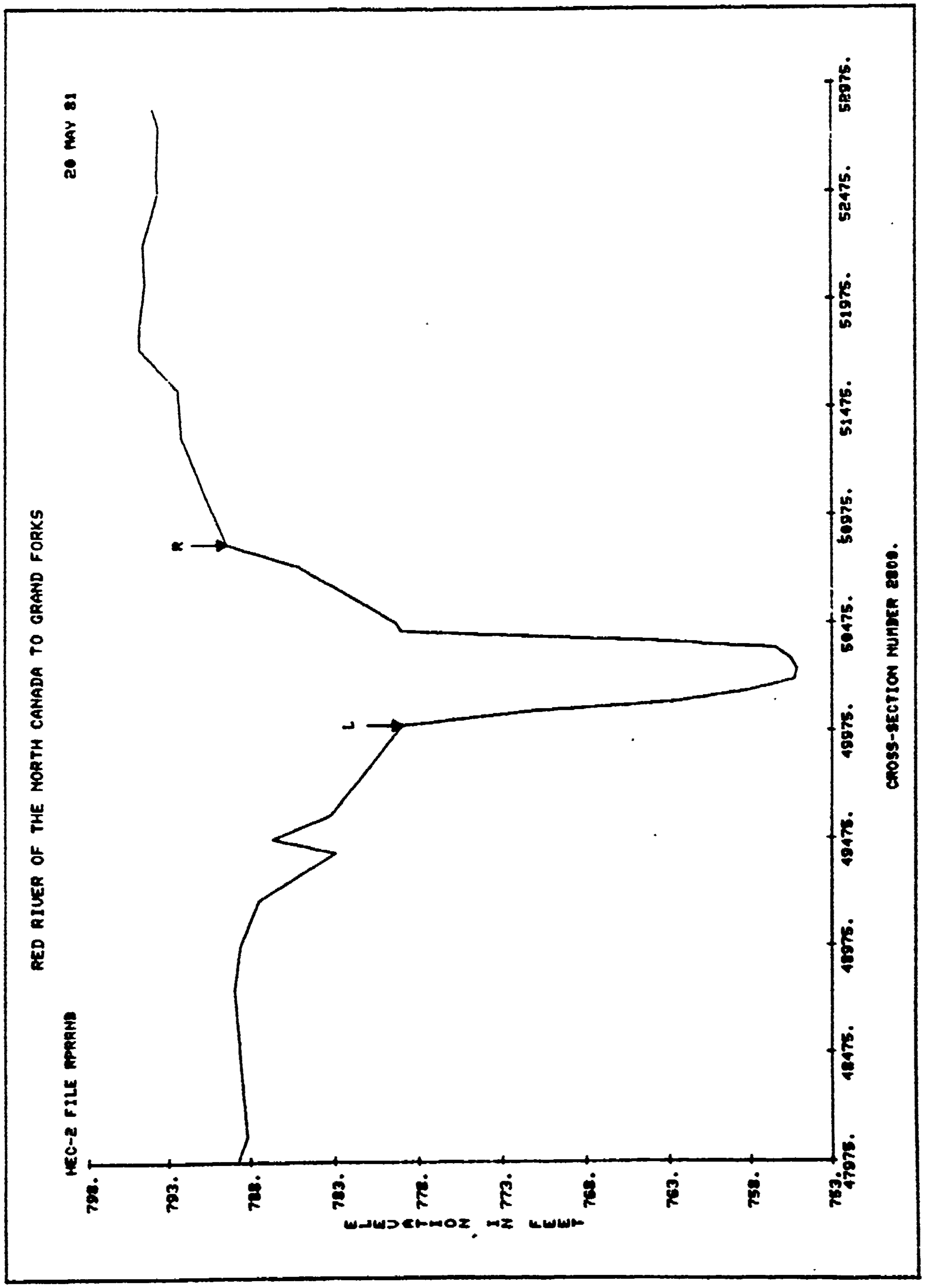
53475.
L
CROSS-SECTION NUMBER


RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRNB
20 MAY 81
ELEVATION IN FEET
798.
793.
788.
783.
778.
773.
768.
763.
758.
753.
47975.
48475.
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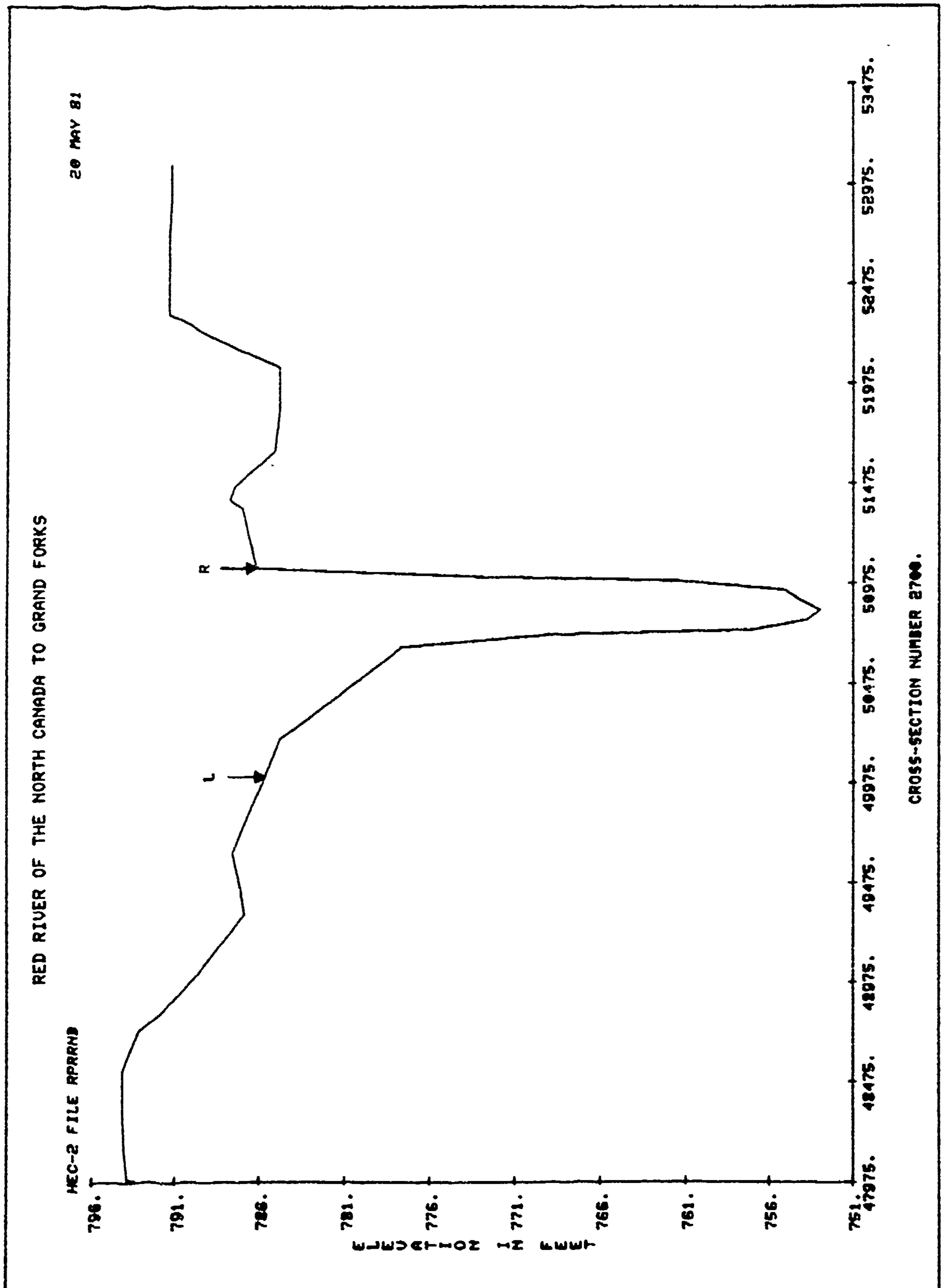
CROSS-SECTION NUMBER 2800.



HEC-2 FILE RPRRNB
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
20 MAY 81
ELEVATION IN FEET
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791.
786.
781.
776.
771.
766.
761.
756.
751.
47975.
48475.
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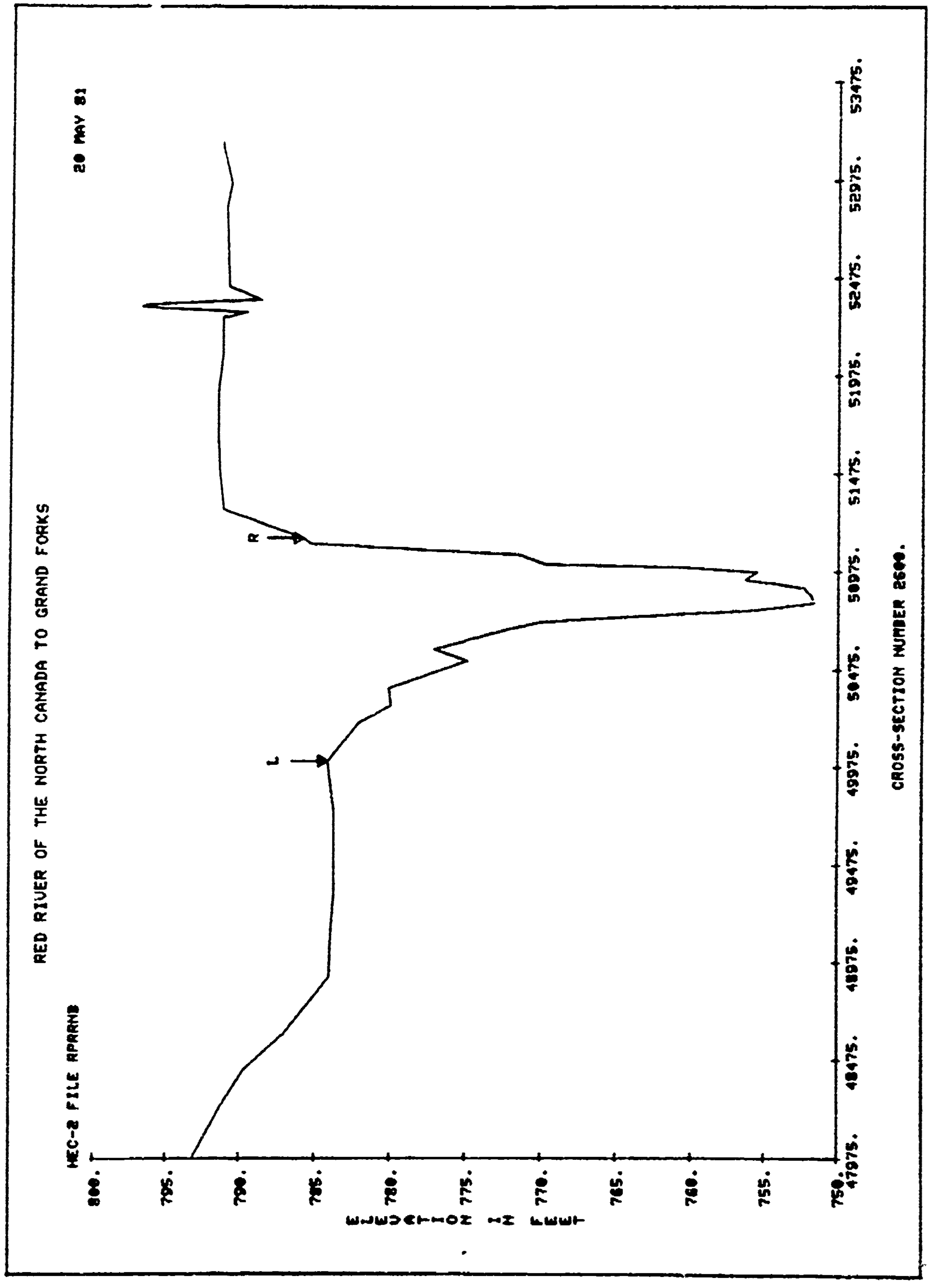
CROSS-SECTION NUMBER 2700.


RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRNB
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ELEVATION IN FEET
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790.
785.
780.
775.
770.
765.
760.
755.
750.
47975.
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48975.
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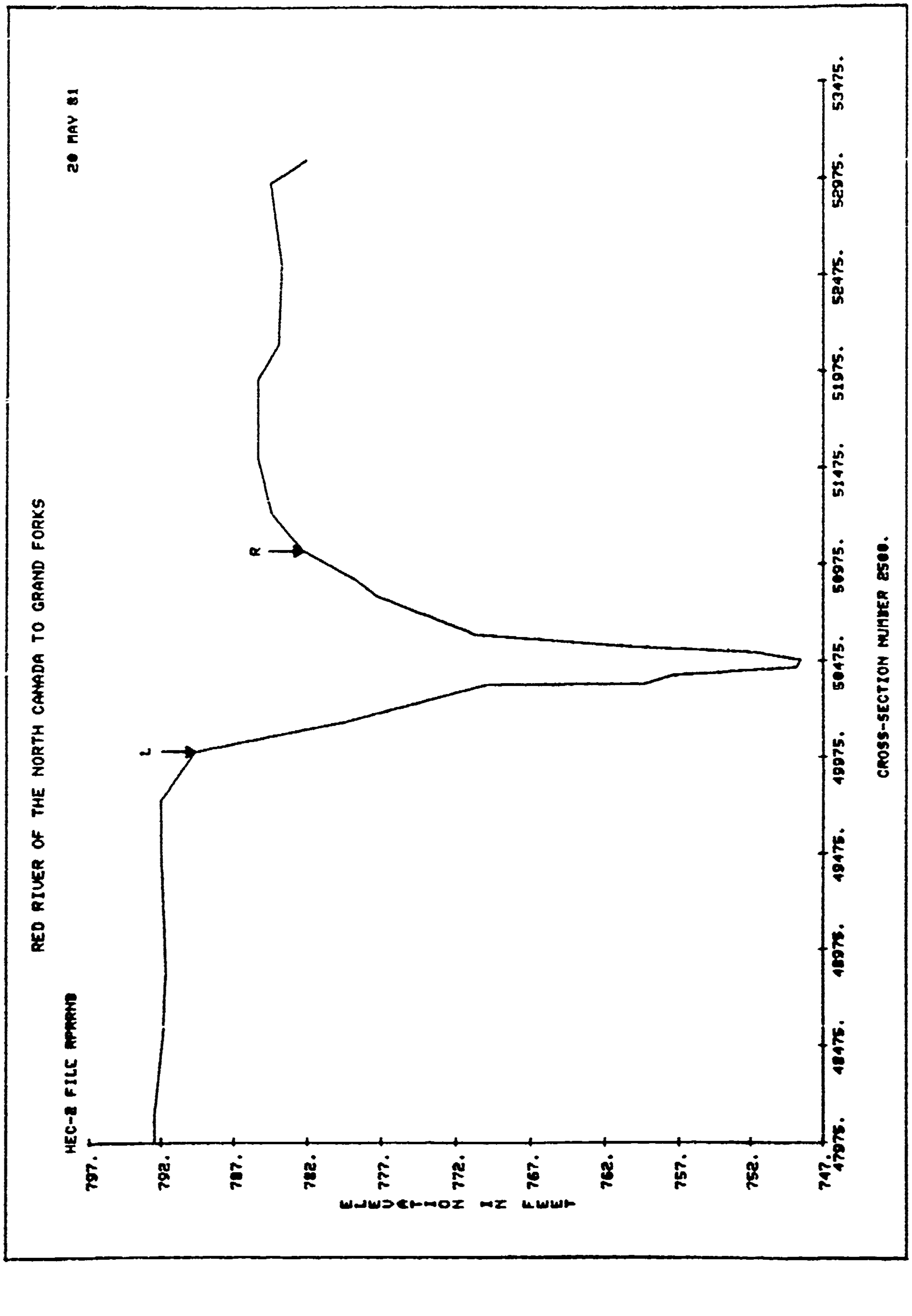
CROSS-SECTION NUMBER 2600.
L
R



HEC-2 FILE
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
20 MAY 81
L
R
ELEVATION IN FEET
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777.
772.
767.
762.
757.
752.
747.
47975.
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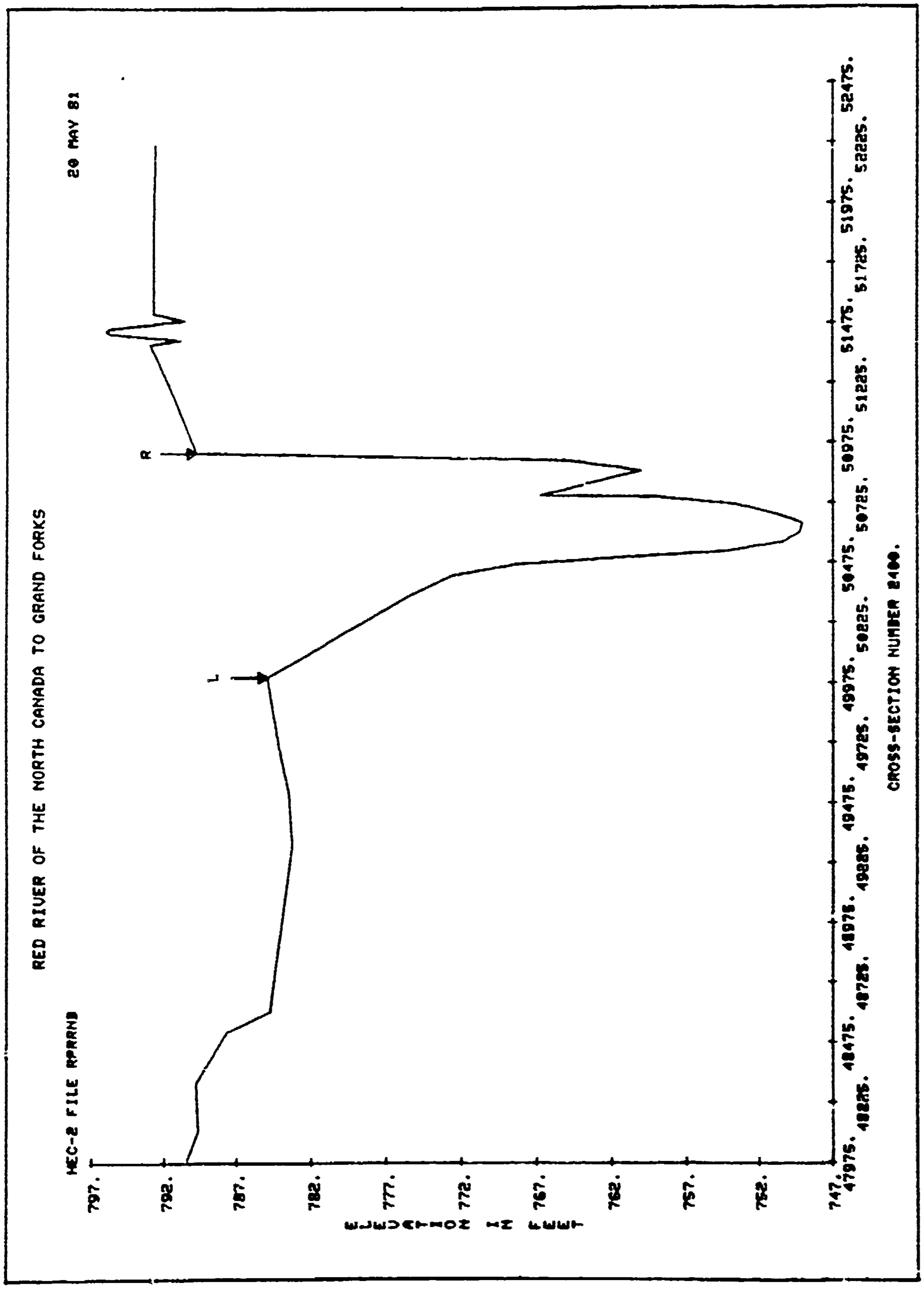

RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRNB
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ELEVATION IN FEET
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777.
772.
767.
762.
757.
752.
747.
L
R
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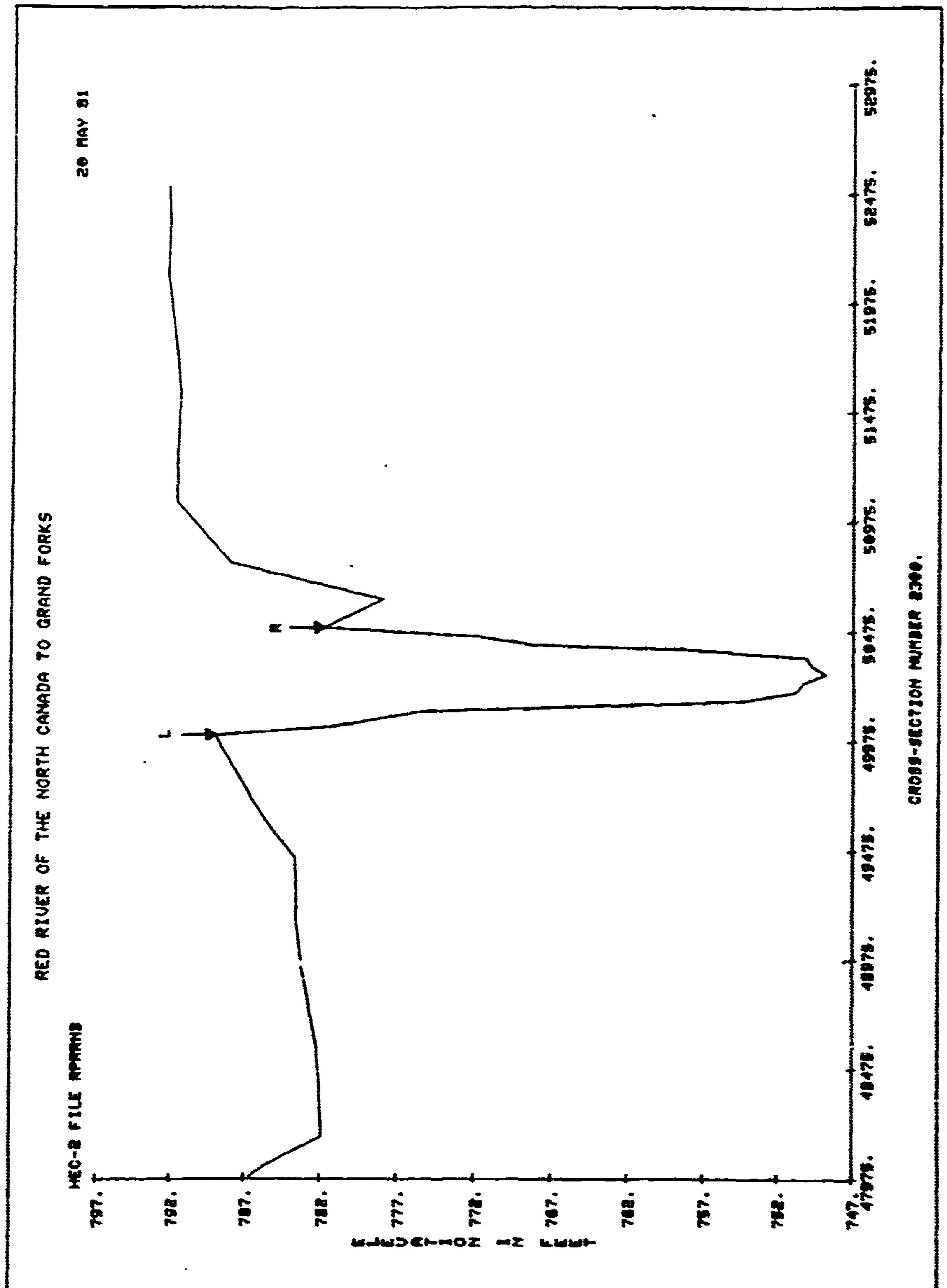

RED RIVER OF THE NORTH CANADA TO GRAND FORKS
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HEC-2 FILE
ELEVATION IN FEET
797.
792.
787.
782.
777.
772.
767.
762.
757.
752.
747.
47975.
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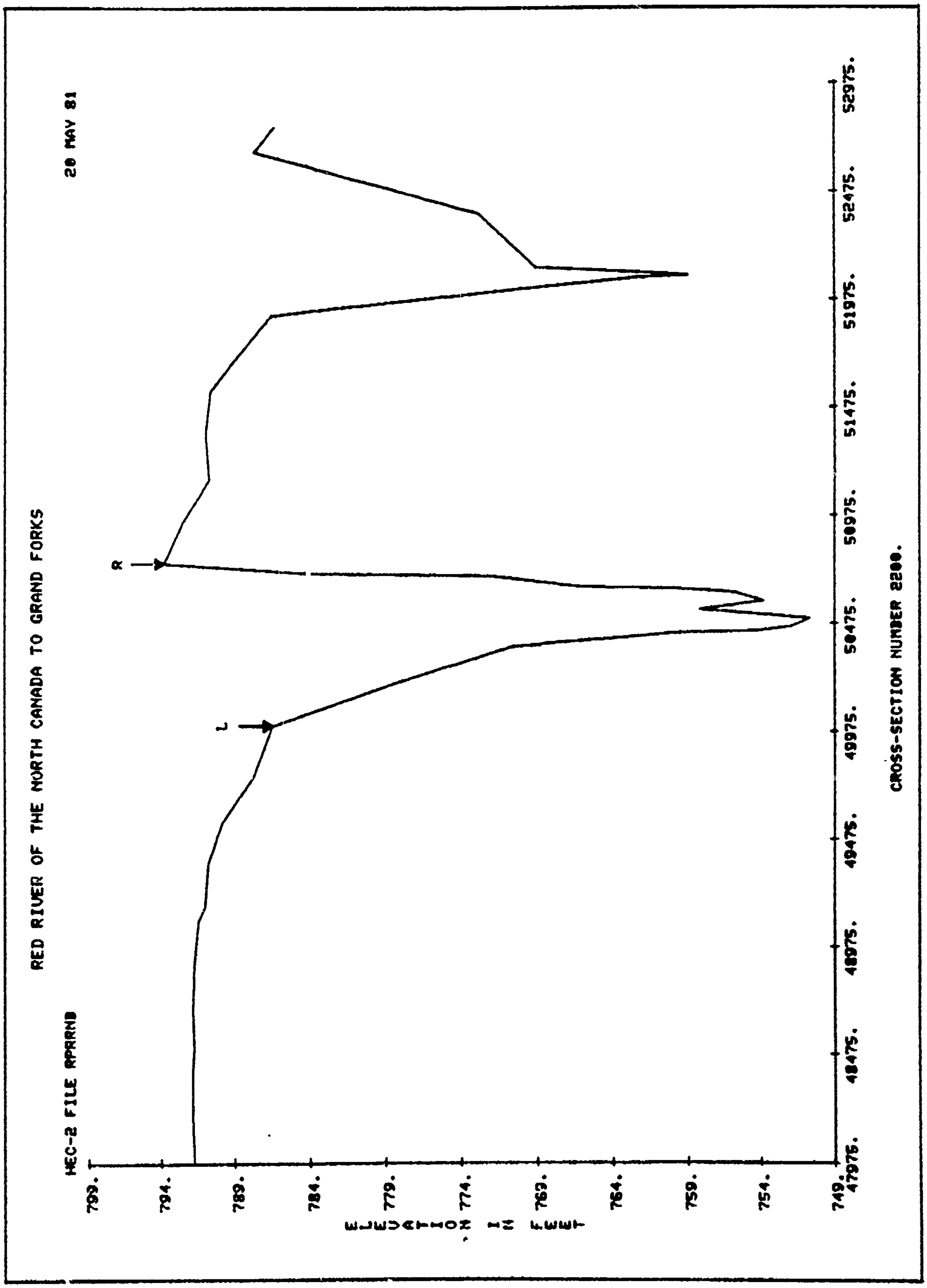
HEC-2 FILE RPARNB
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
20 MAY 81
R
L
ELEVATION IN FEET
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794.
789.
784.
779.
774.
769.
764.
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754.
749.
47975.
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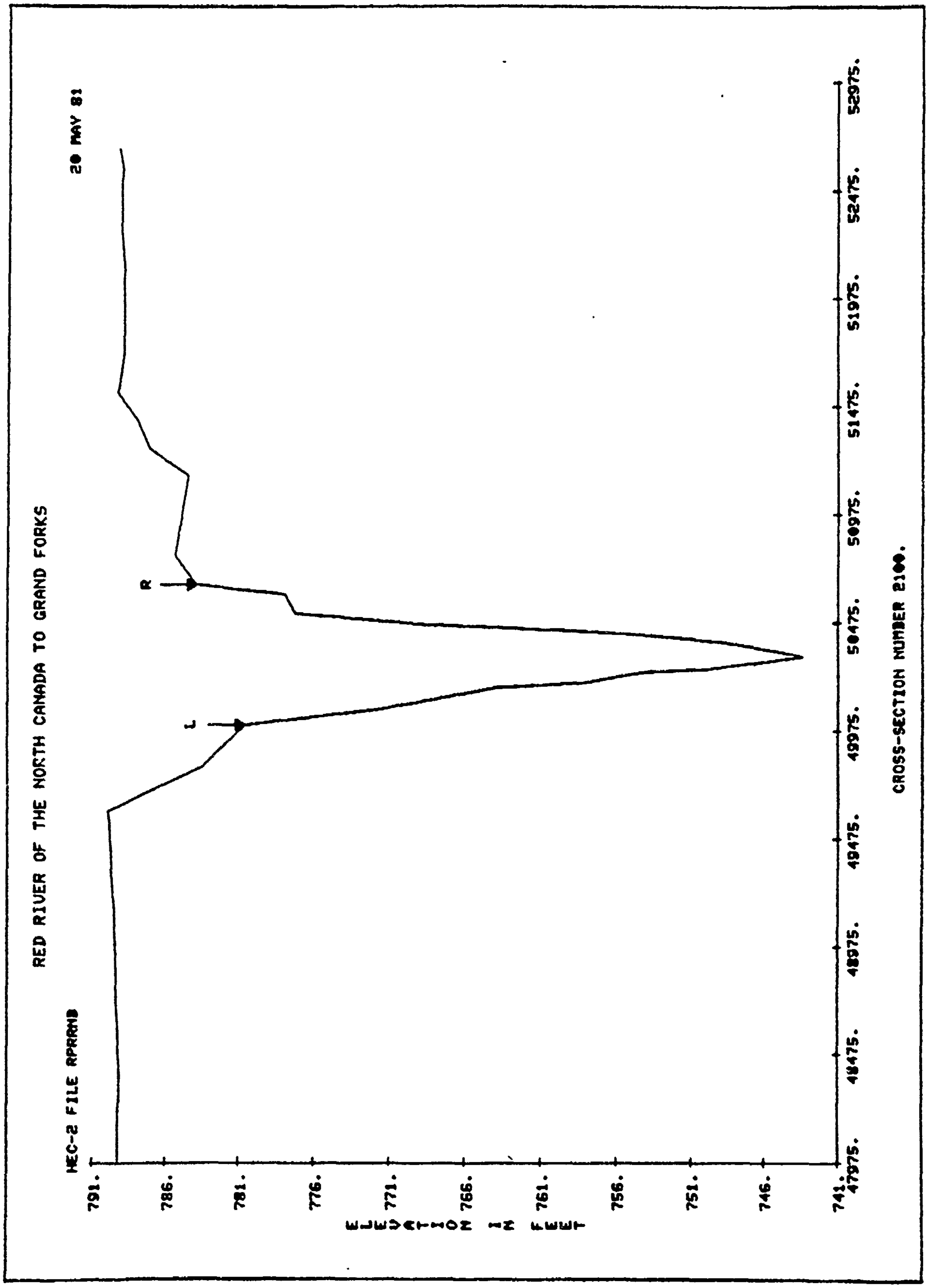
CROSS-SECTION NUMBER 2200.



RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRNB
20 MAY 81
R
L
ELEVATION IN FEET
791.
786.
781.
776.
771.
766.
761.
756.
751.
746.
741.
47975.
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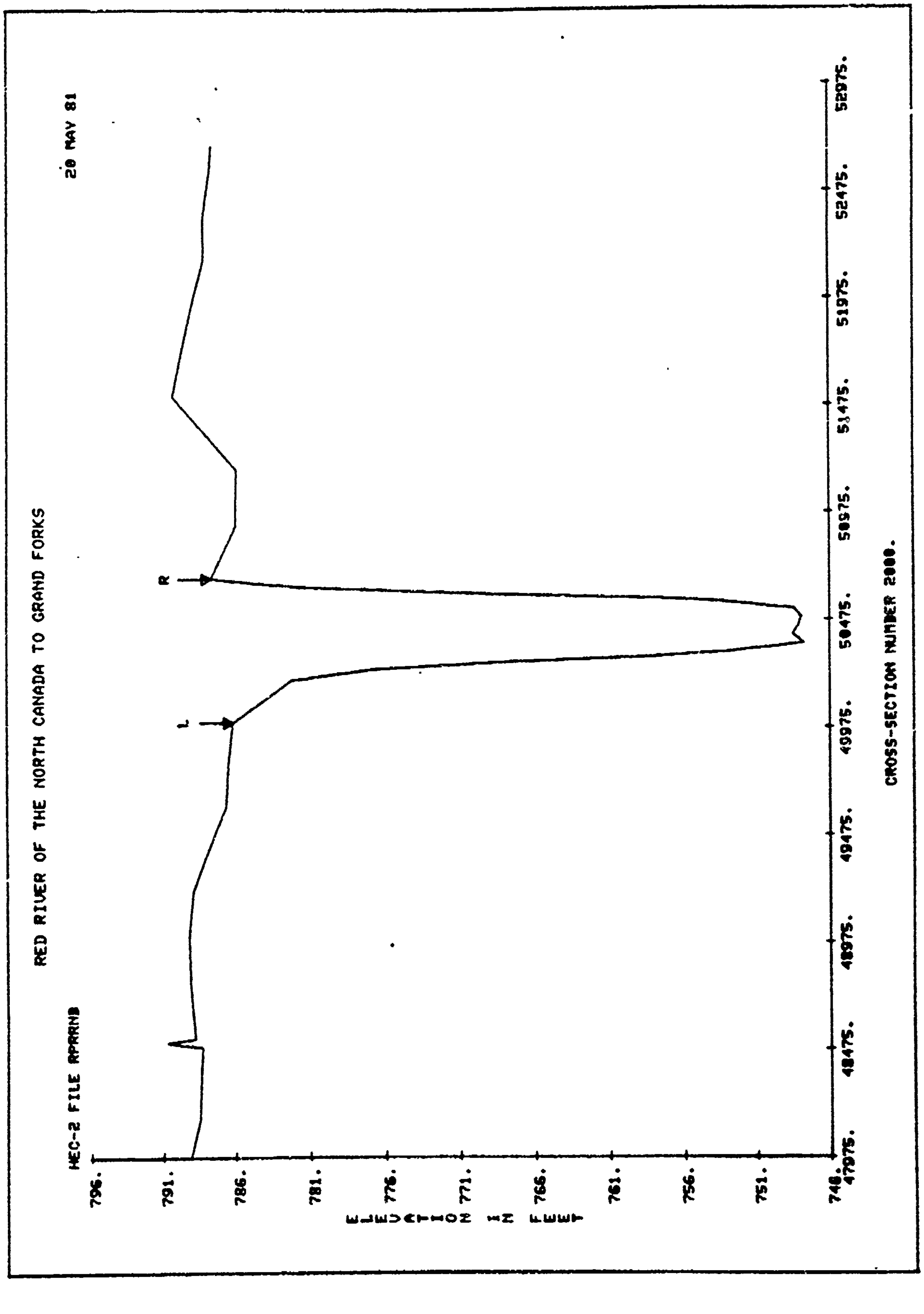

HEC-2 FILE RPRRNB
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
20 MAY 81
R
L
ELEVATION IN FEET
796.
791.
786.
781.
776.
771.
766.
761.
756.
751.
746.
47975.
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49975.
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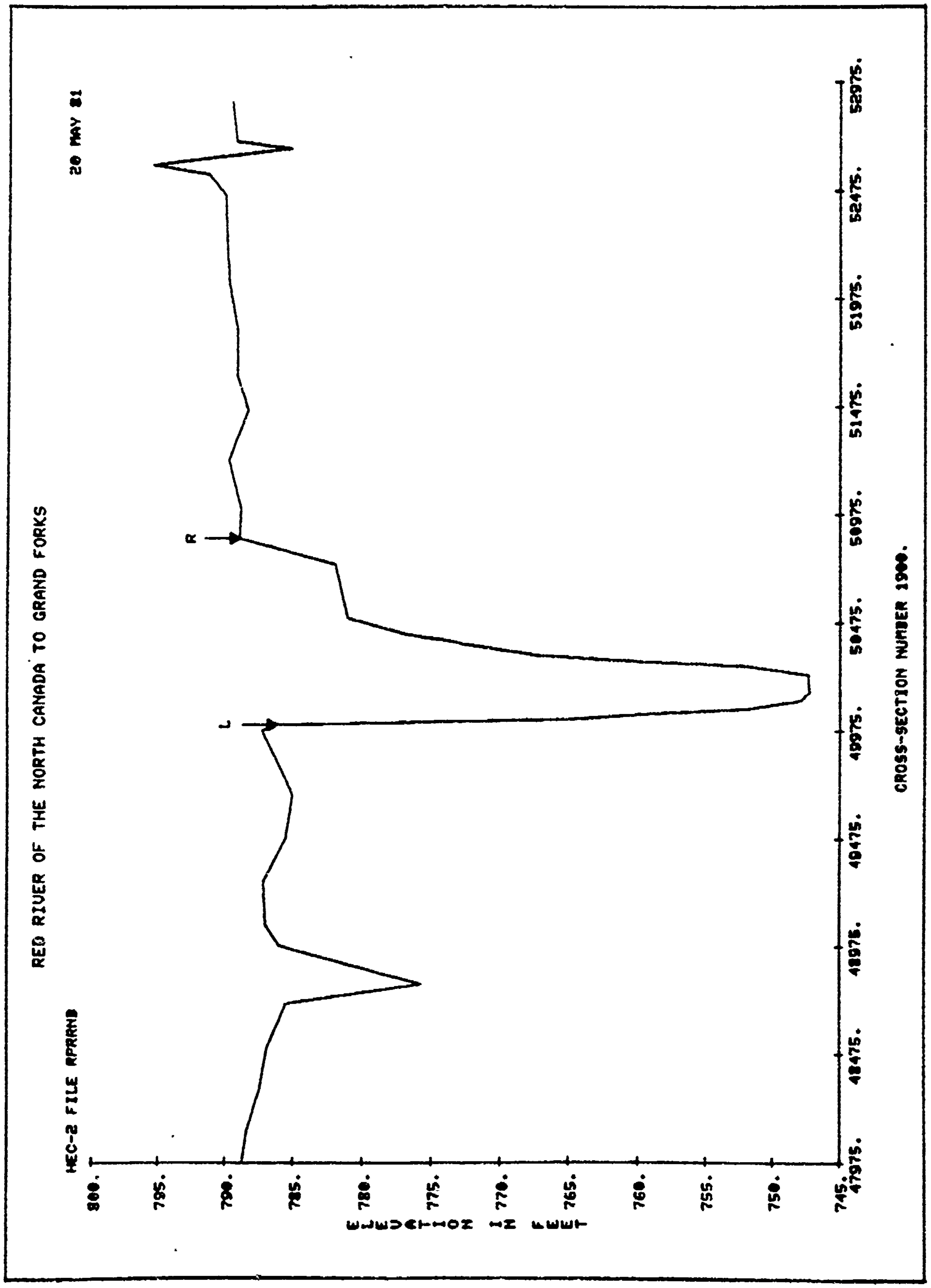
CROSS-SECTION NUMBER 2000.


RED RIVER OF THE NORTH CANADA TO GRAND FORKS
20 MAY 81
HEC-2 FILE RPRRNB
ELEVATION IN FEET
800.
795.
790.
785.
780.
775.
770.
765.
760.
755.
750.
745.
47975.
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48975.
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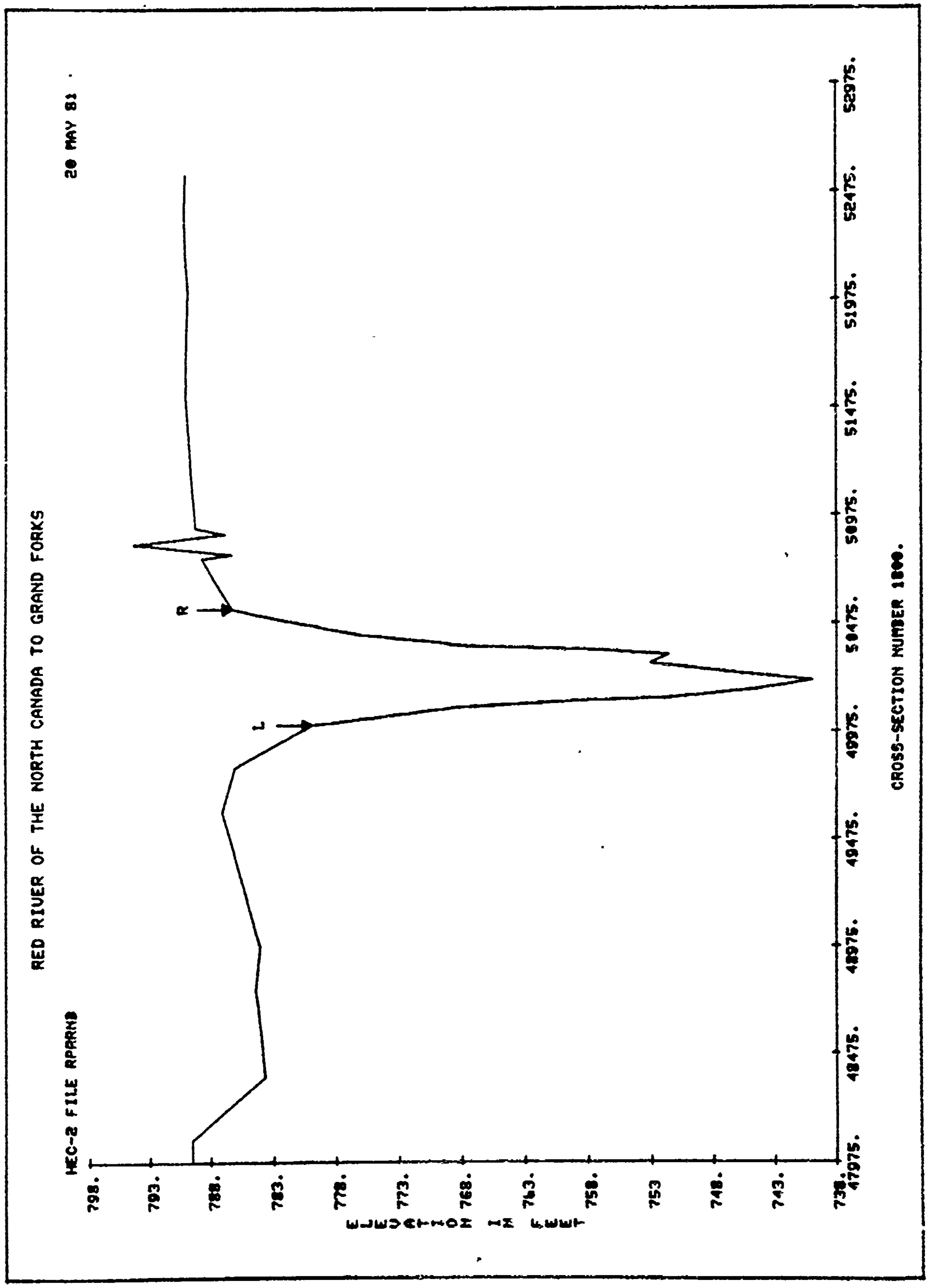
50475.
50975.
51475.
51975.
52475.
52975.
L
R
CROSS-SECTION NUMBER 1900.


HEC-2 FILE RPARNB
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
20 MAY 81
ELEVATION IN FEET
798.
793.
788.
783.
778.
773.
768.
763.
758.
753.
748.
743.
738.
47975.
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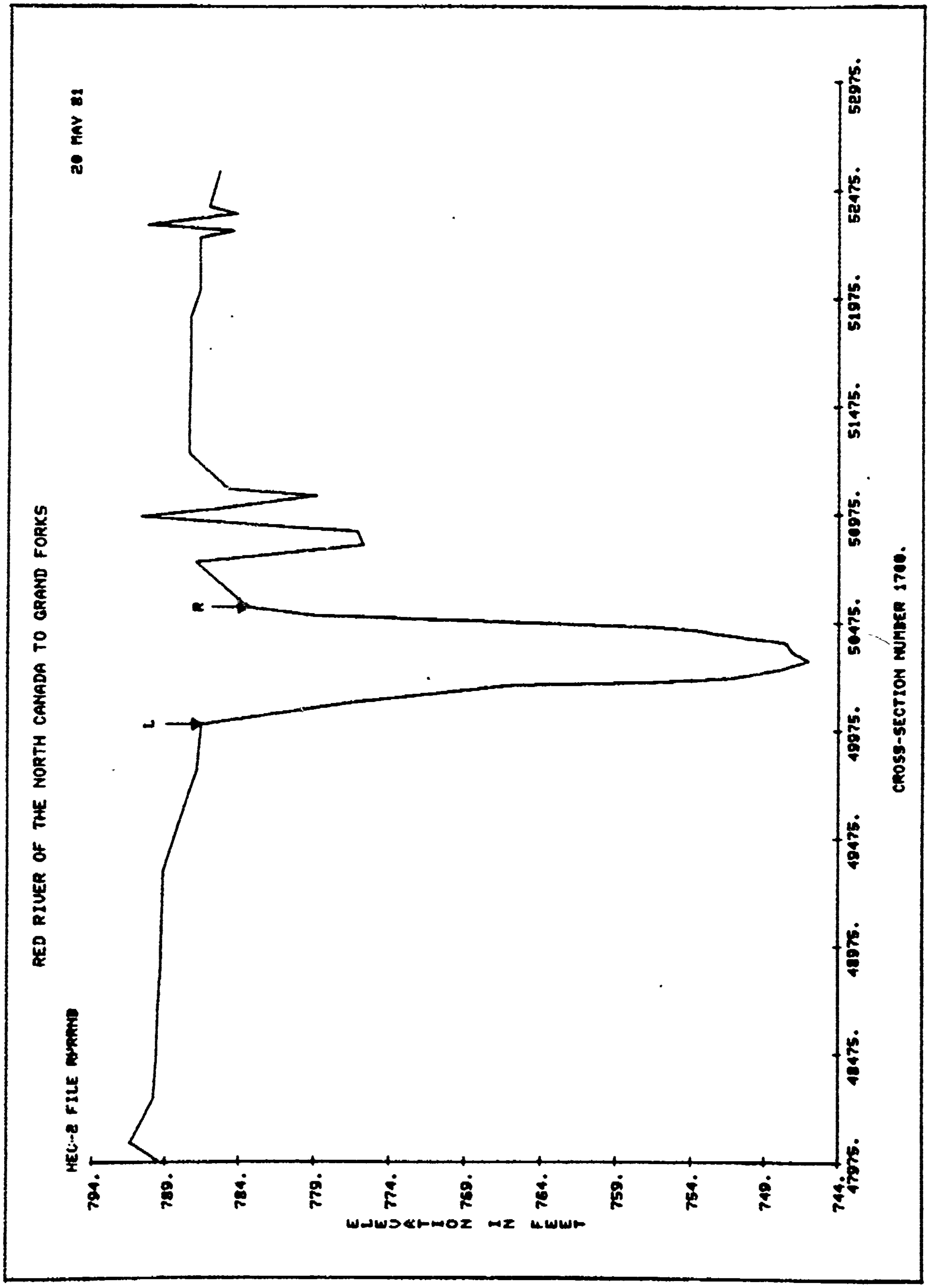
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
20 MAY 81
HEC-2 FILE RVRRND
ELEVATION IN FEET
794.
789.
784.
779.
774.
769.
764.
759.
754.
749.
744.
47975.
48475.
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50975.
51475.
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52975.
L
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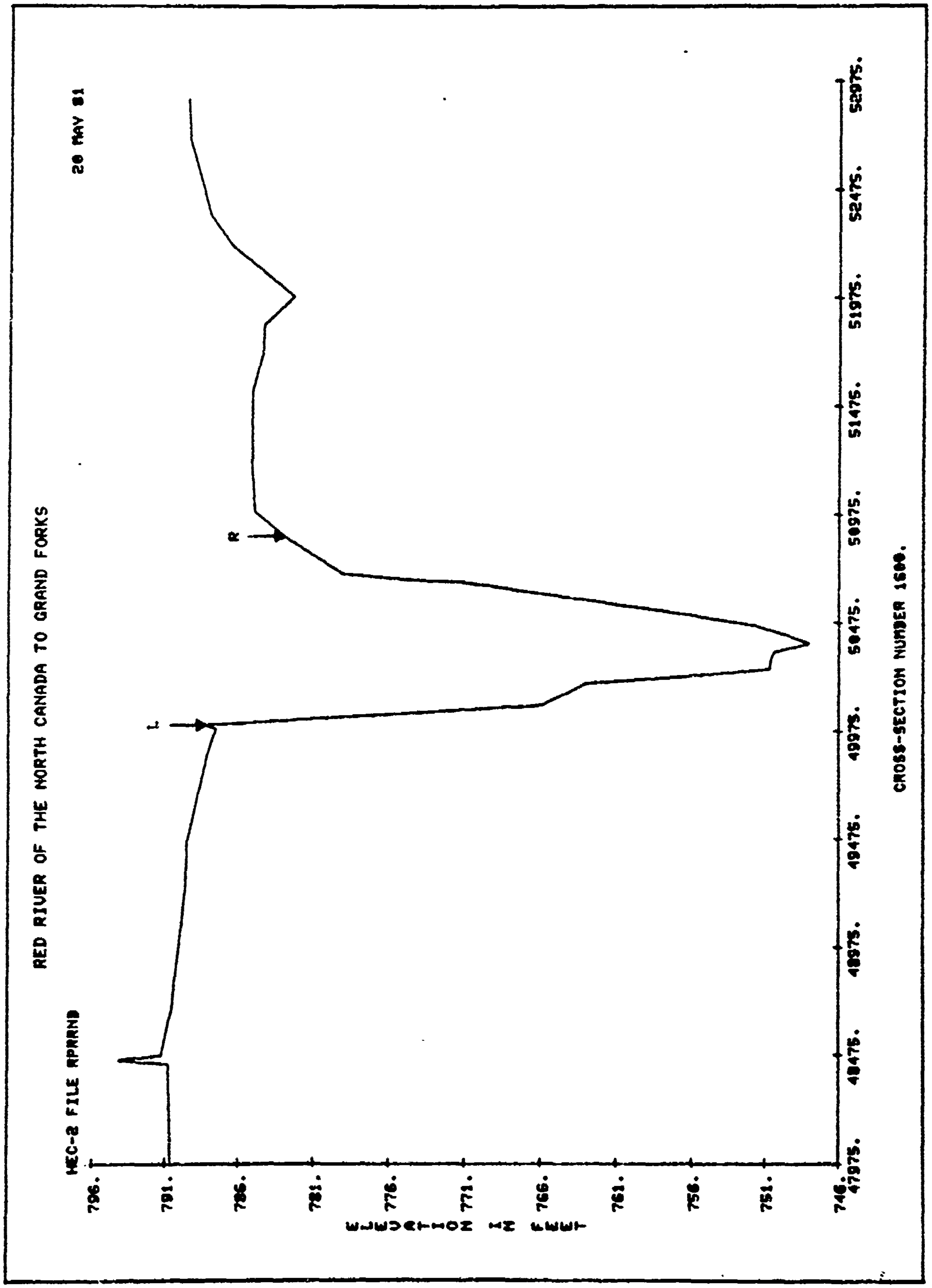
CROSS-SECTION NUMBER 1700.


HEC-2 FILE RPRRNB
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
20 MAY 81
ELEVATION IN FEET
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791.
786.
781.
776.
771.
766.
761.
756.
751.
746.
47975.
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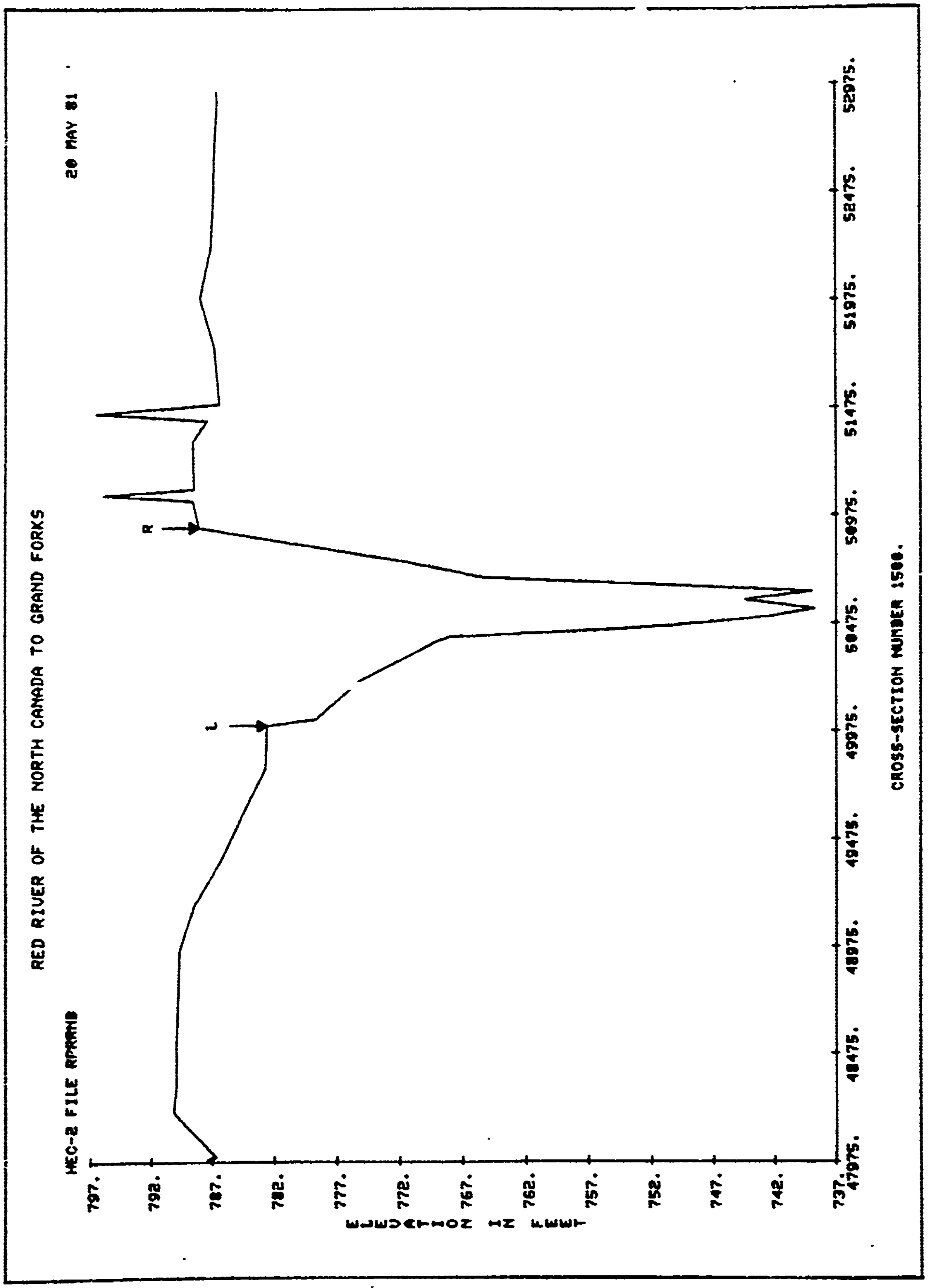
CROSS-SECTION NUMBER 1600.



RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPARNB
20 MAY 81
R
L
ELEVATION IN FEET
797.
792.
787.
782.
777.
772.
767.
762.
757.
752.
747.
742.
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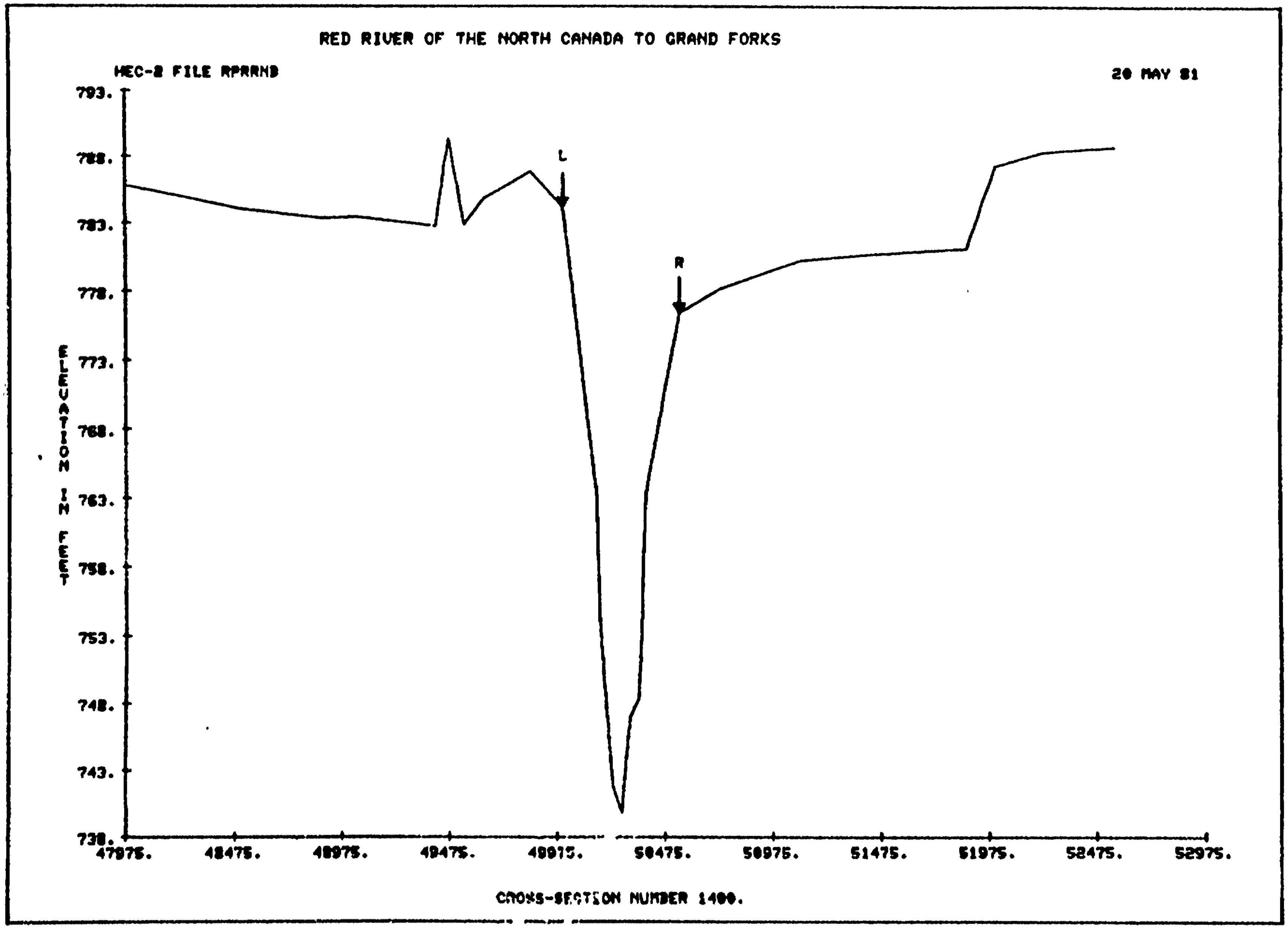
CROSS-SECTION NUMBER 1500.


RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRNB
20 MAY 81
ELEVATION IN FEET
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788.
783.
778.
773.
768.
763.
758.
753.
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743.
738.
L
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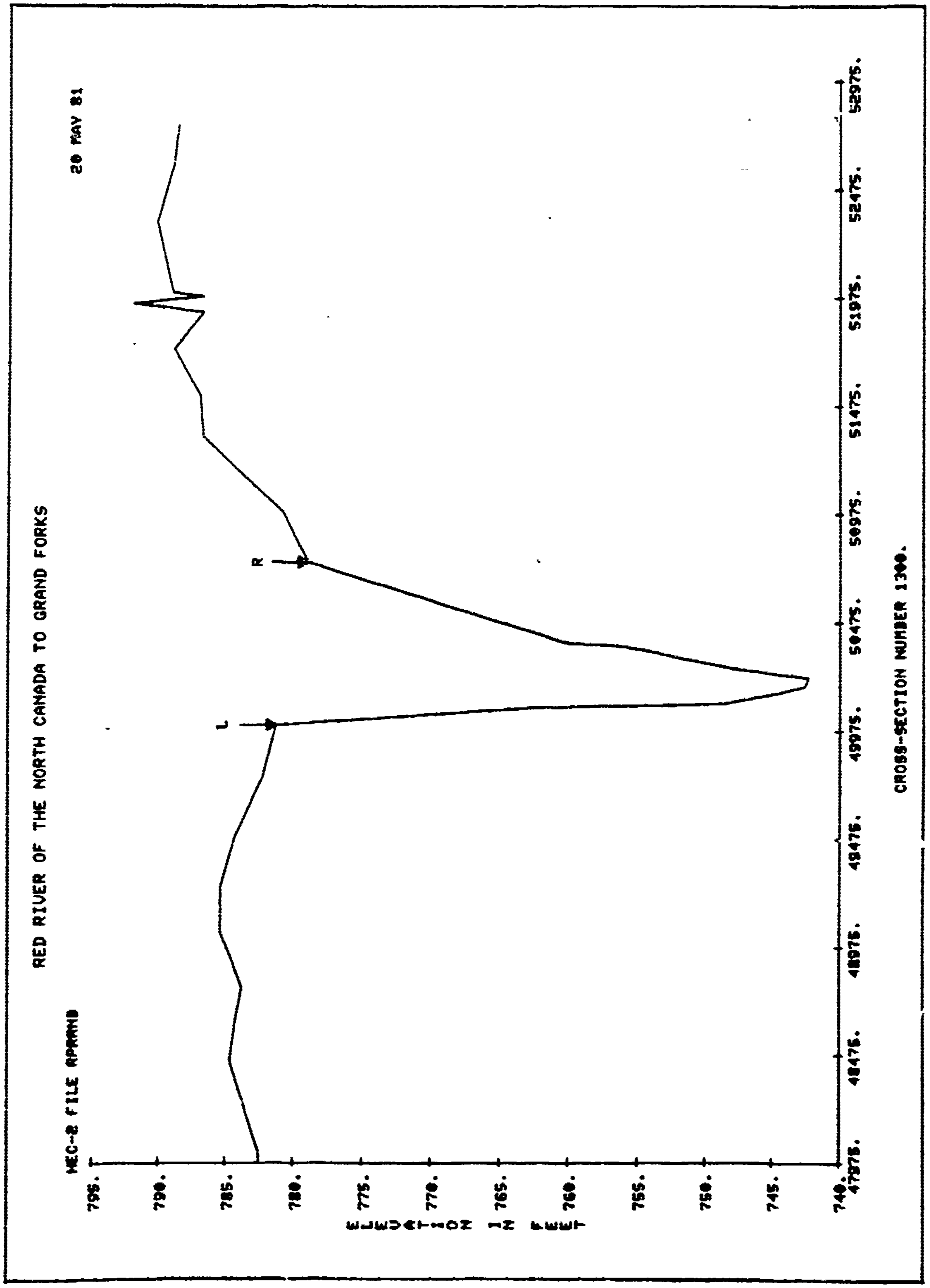
CROSS-SECTION NUMBER 1400.



RED RIVER OF THE NORTH CANADA TO GRAND FORKS
20 MAY 81
HEC-2 FILE RPRAND
ELEVATION IN FEET
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785.
780.
775.
770.
765.
760.
755.
750.
745.
740.
47975.
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51475.
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L
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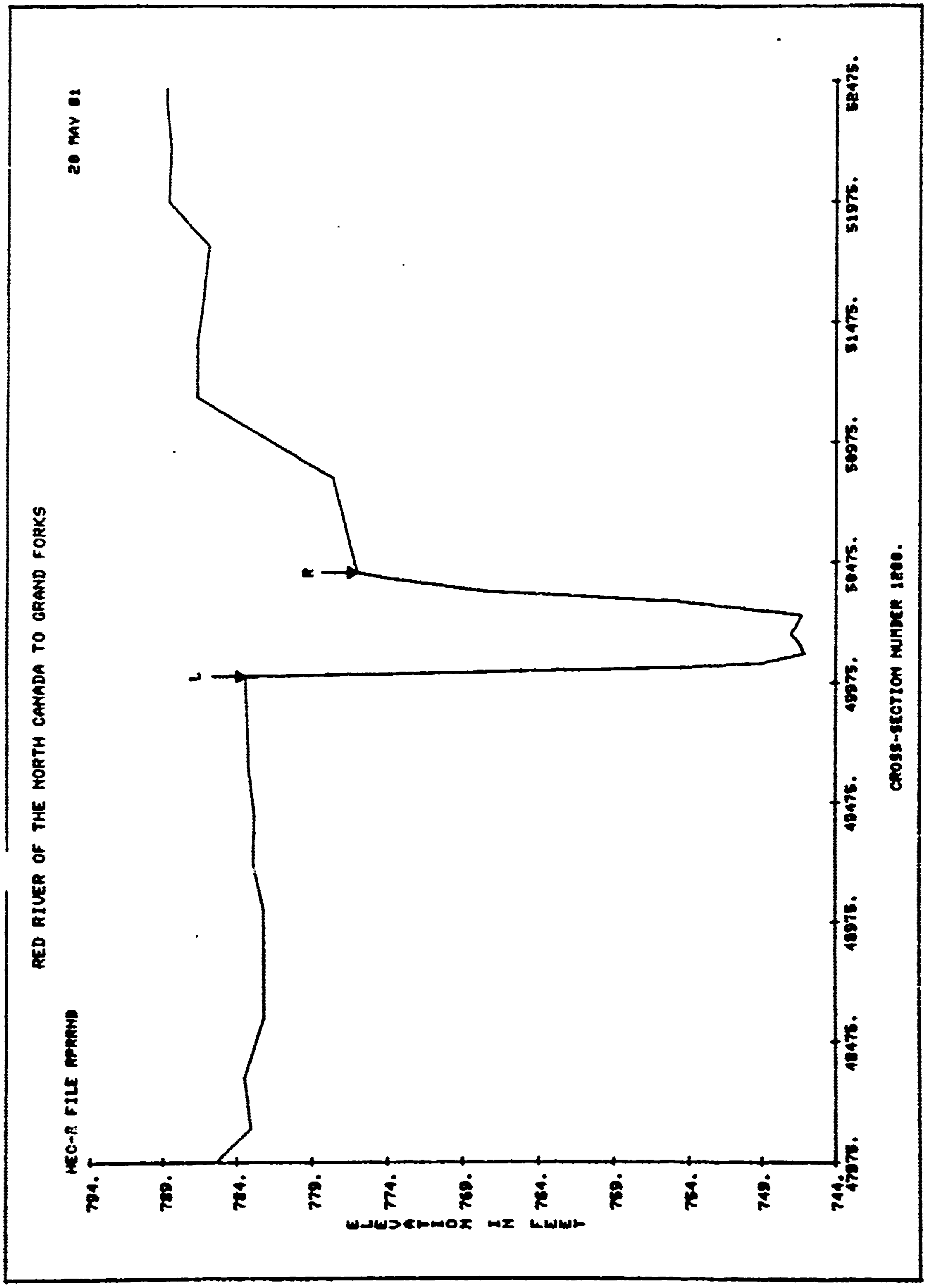
CROSS-SECTION NUMBER 1300.



HEC-2 FILE RPRRND
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
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ELEVATION IN FEET
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779.
774.
769.
764.
759.
754.
749.
744.
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52475.
L
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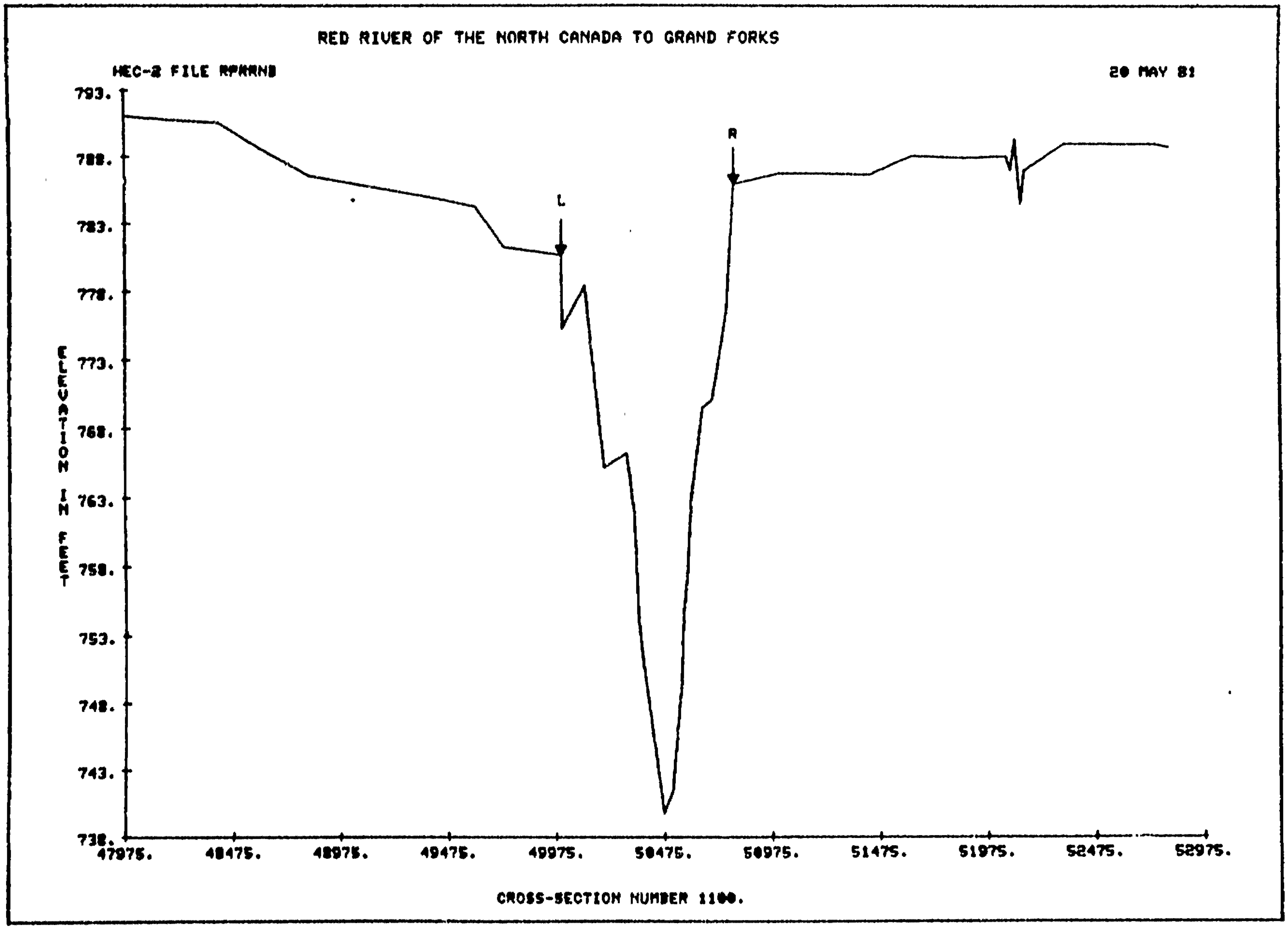

RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRNB
20 MAY 81
ELEVATION IN FEET
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788.
783.
778.
773.
768.
763.
758.
753.
748.
743.
738.
47975.
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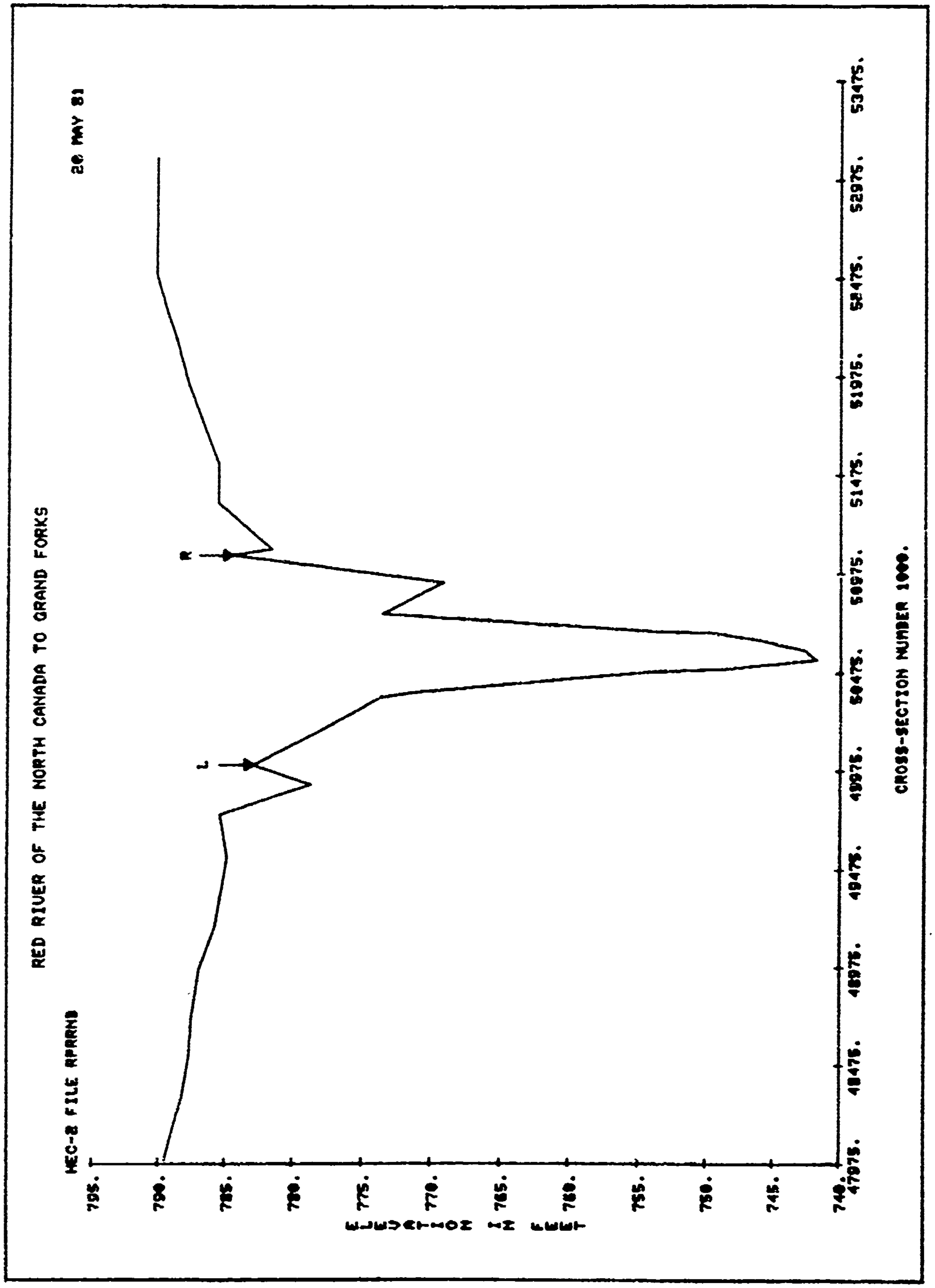
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20 MAY 81
HEC-2 FILE RPRRNB
ELEVATION IN FEET
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785.
780.
775.
770.
765.
760.
755.
750.
745.
740.
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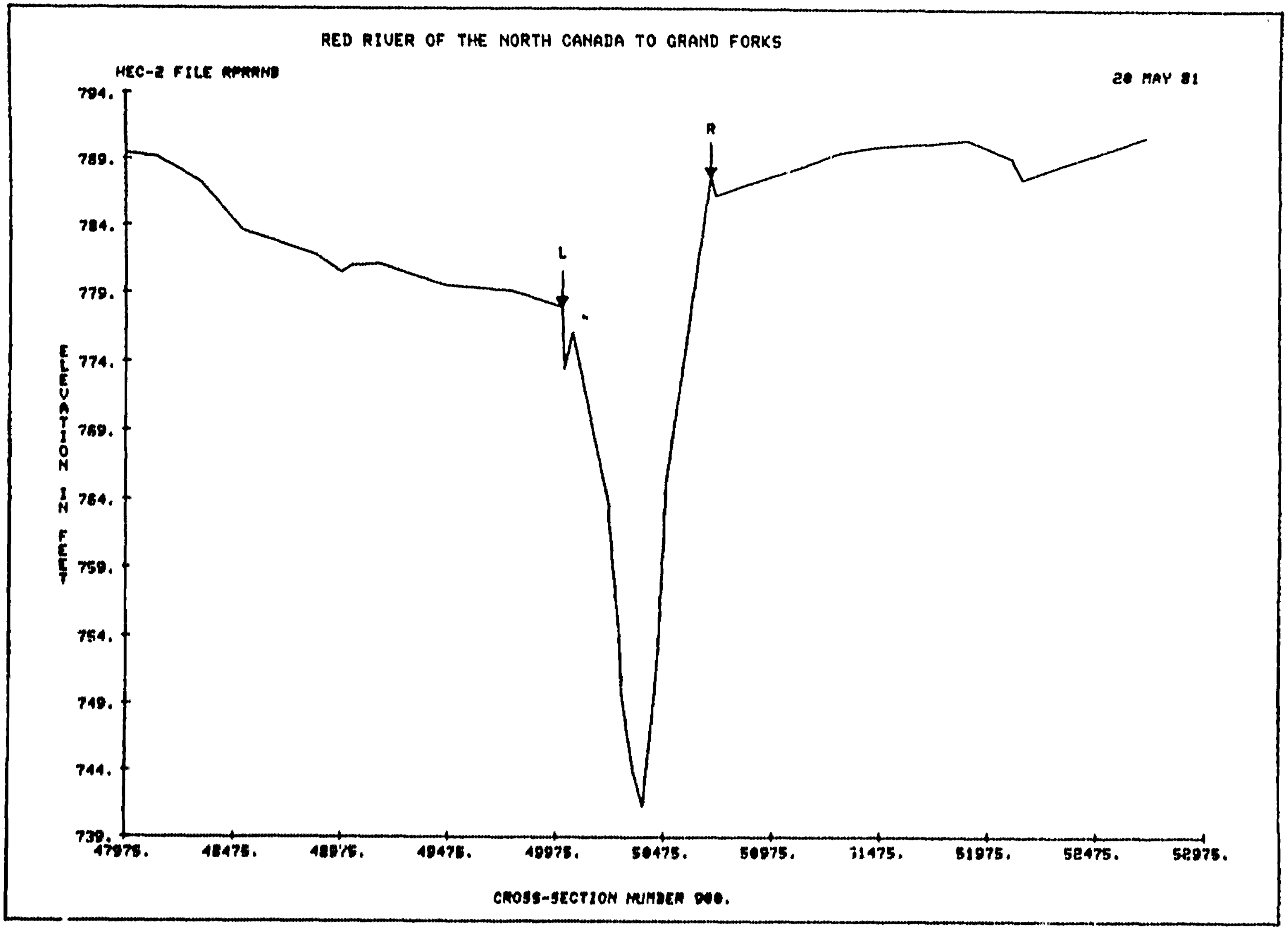
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRNB
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779.
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769.
764.
759.
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749.
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739.
ELEVATION IN FEET
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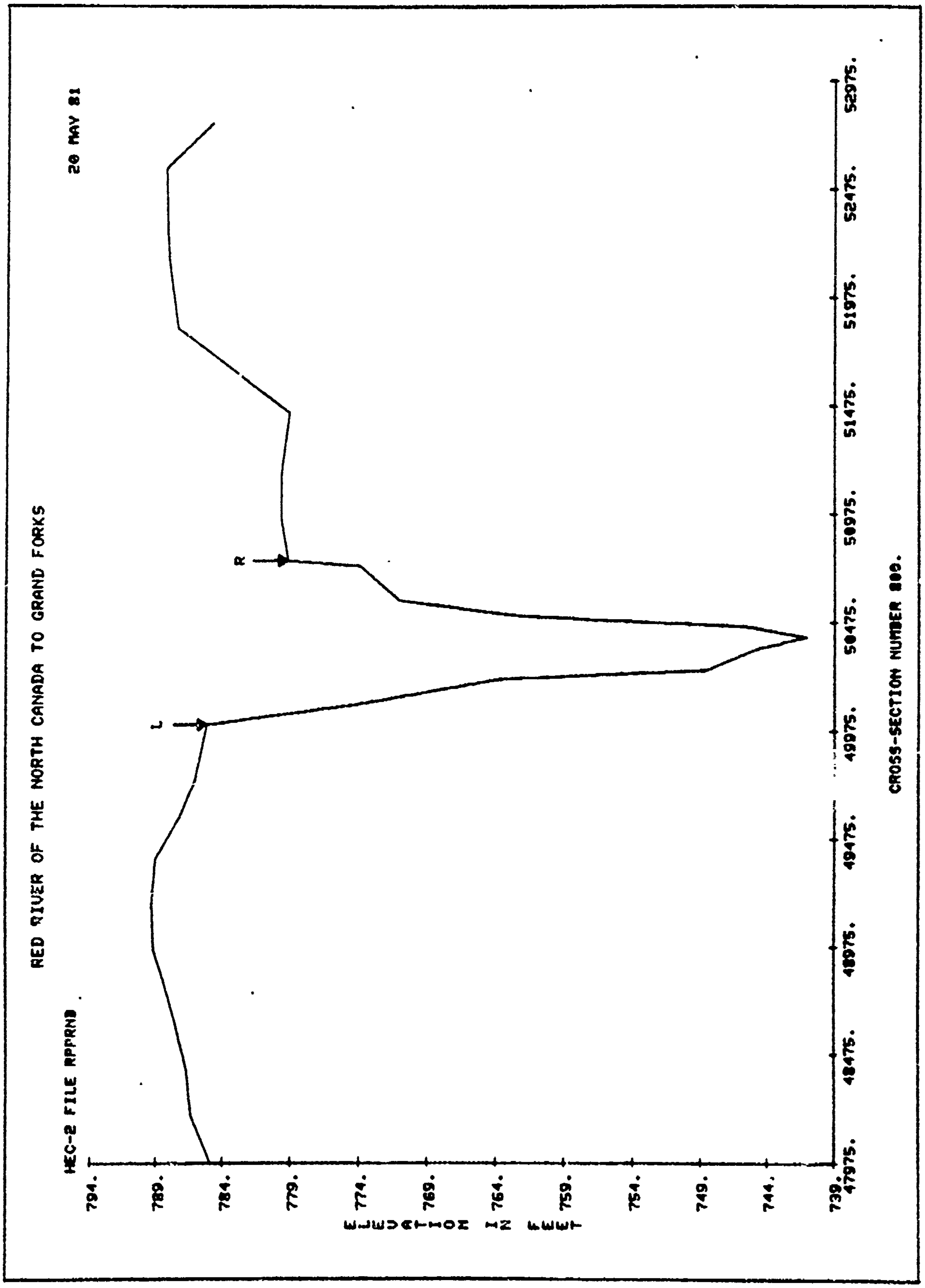
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPPRNB
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ELEVATION IN FEET
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774.
769.
764.
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744.
739.
47975.
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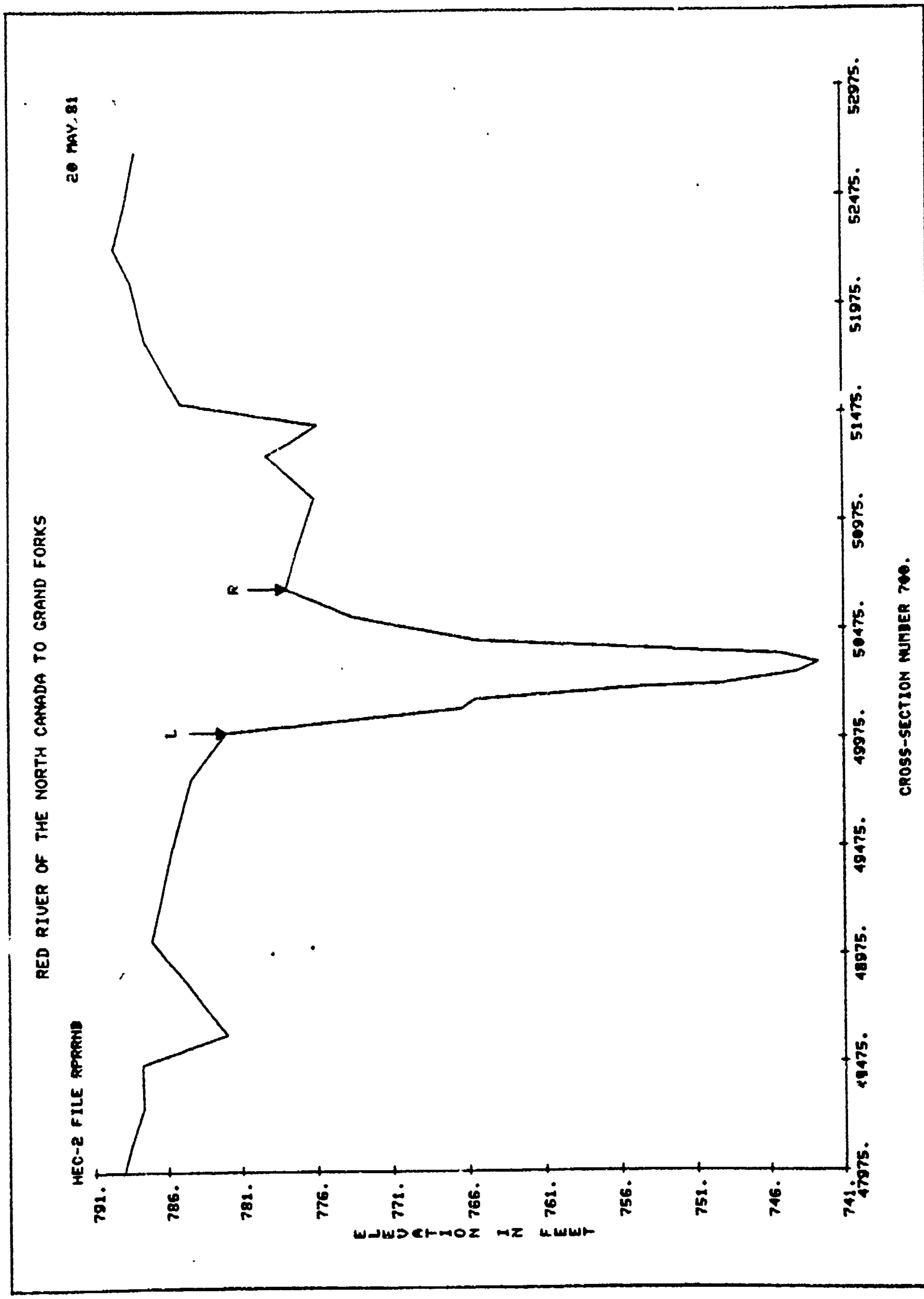
HEC-2 FILE RPRRNB
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
20 MAY 81
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R
ELEVATION IN FEET
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771.
766.
761.
756.
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746.
741.
47975.
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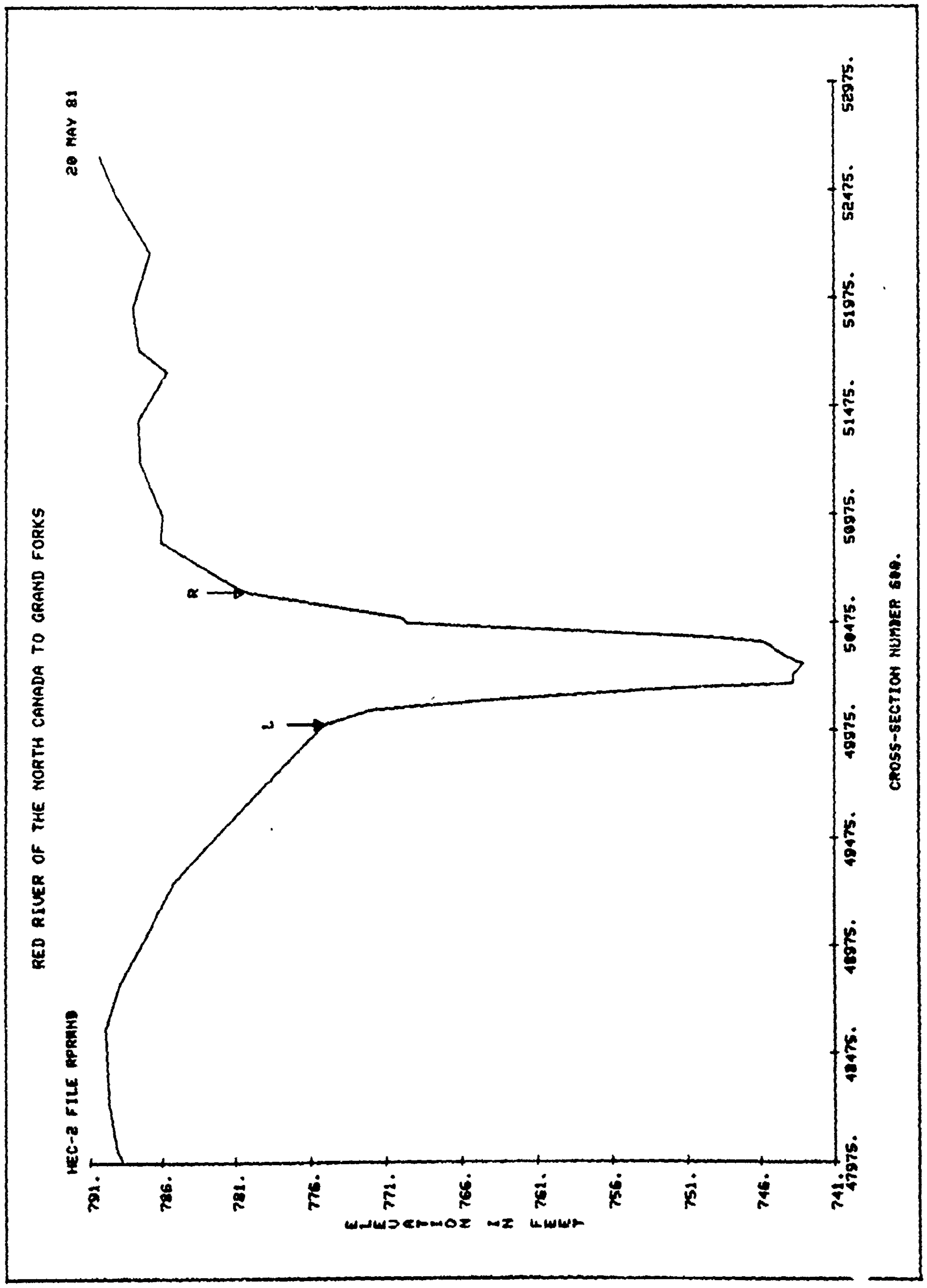
HEC-2 FILE RPRMHD
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
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776.
771.
766.
761.
756.
751.
746.
741.
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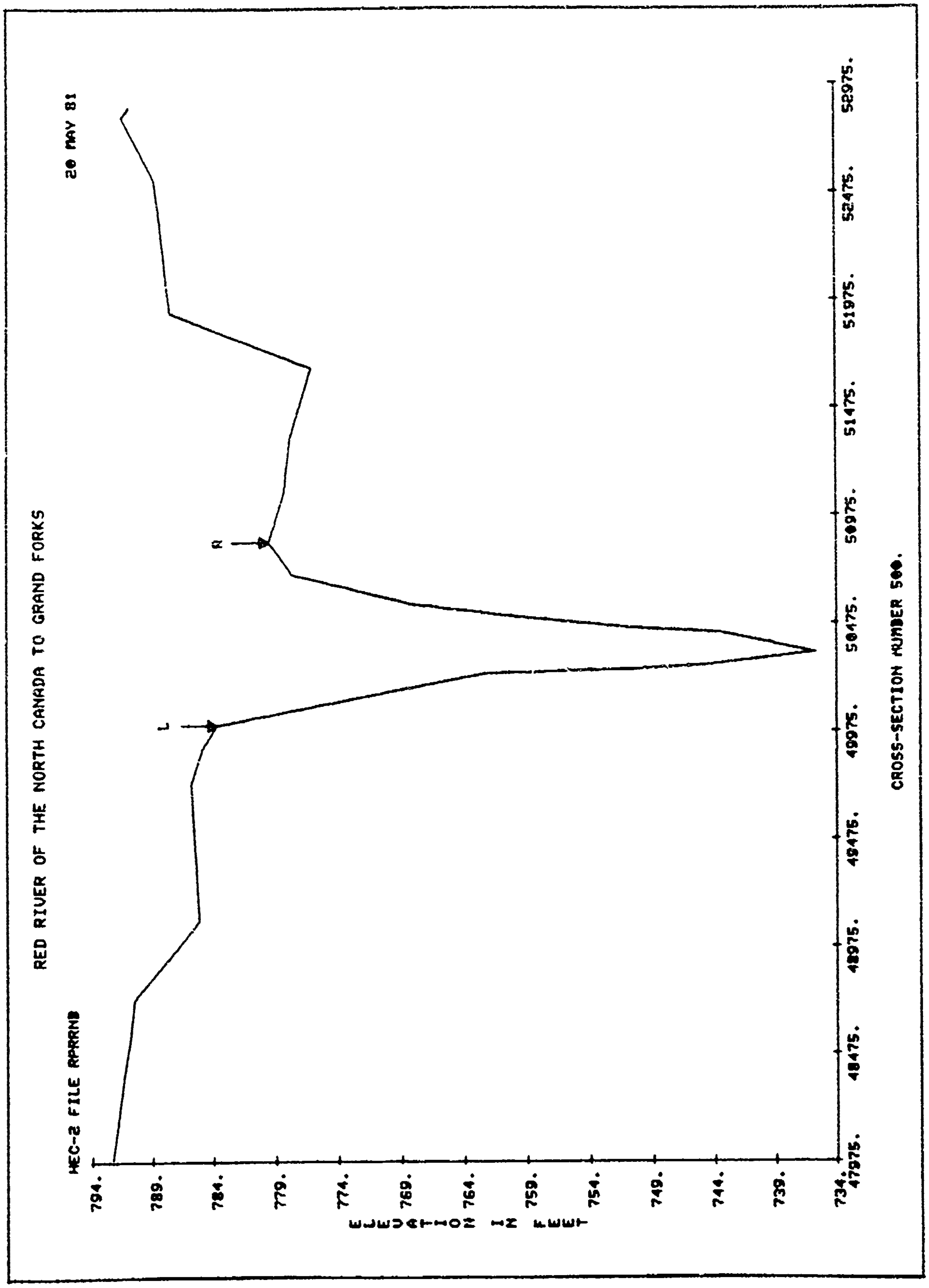
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRNB
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ELEVATION IN FEET
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774.
769.
764.
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734.
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L
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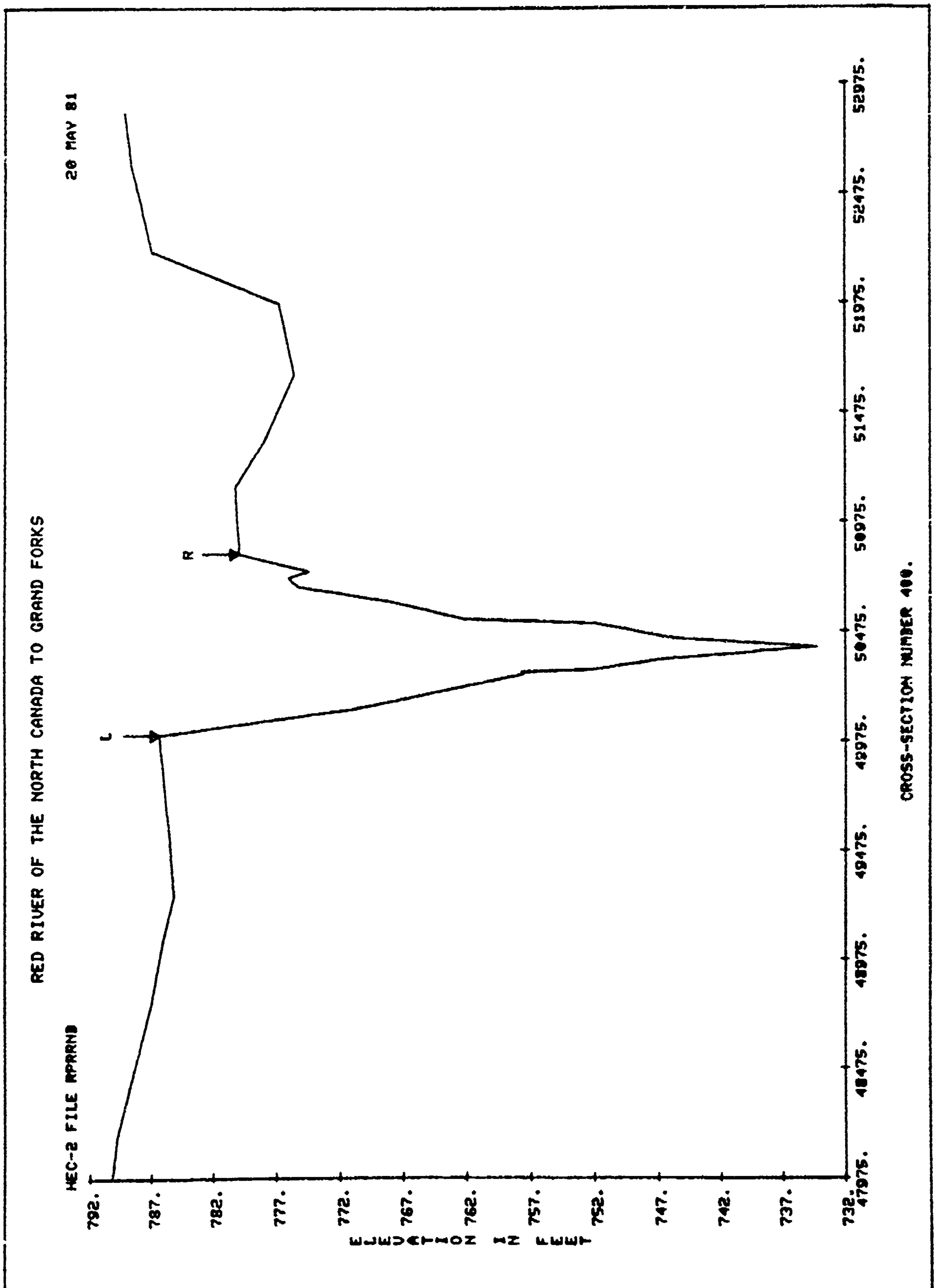
CROSS-SECTION NUMBER 500.



HEC-2 FILE RPRRNB
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
20 MAY 81
L
R
ELEVATION IN FEET
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787.
782.
777.
772.
767.
762.
757.
752.
747.
742.
737.
732.
47975.
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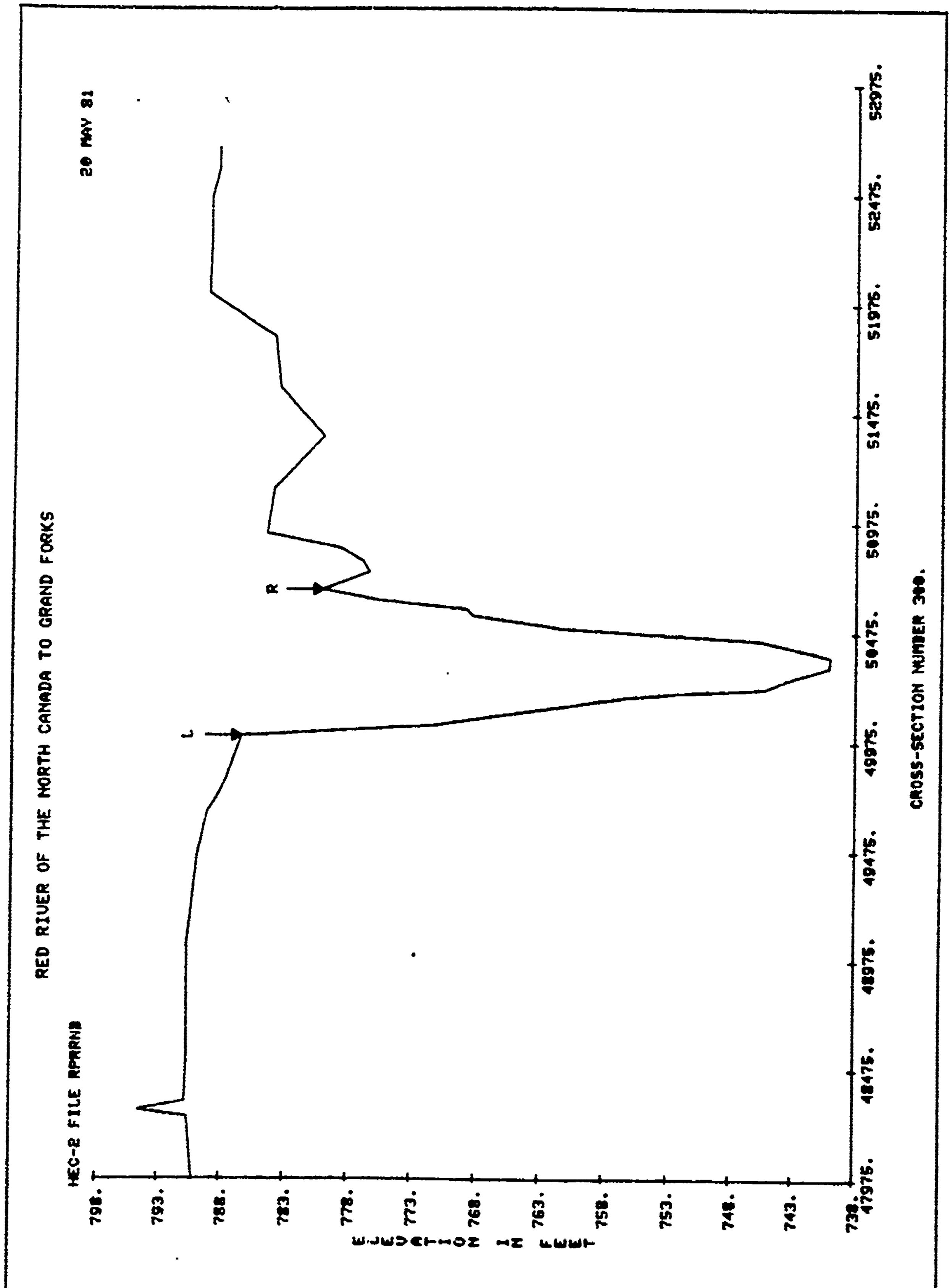

RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRNB
20 MAY 81
ELEVATION IN FEET
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793.
788.
783.
778.
773.
768.
763.
758.
753.
748.
743.
738.
47975.
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L
R
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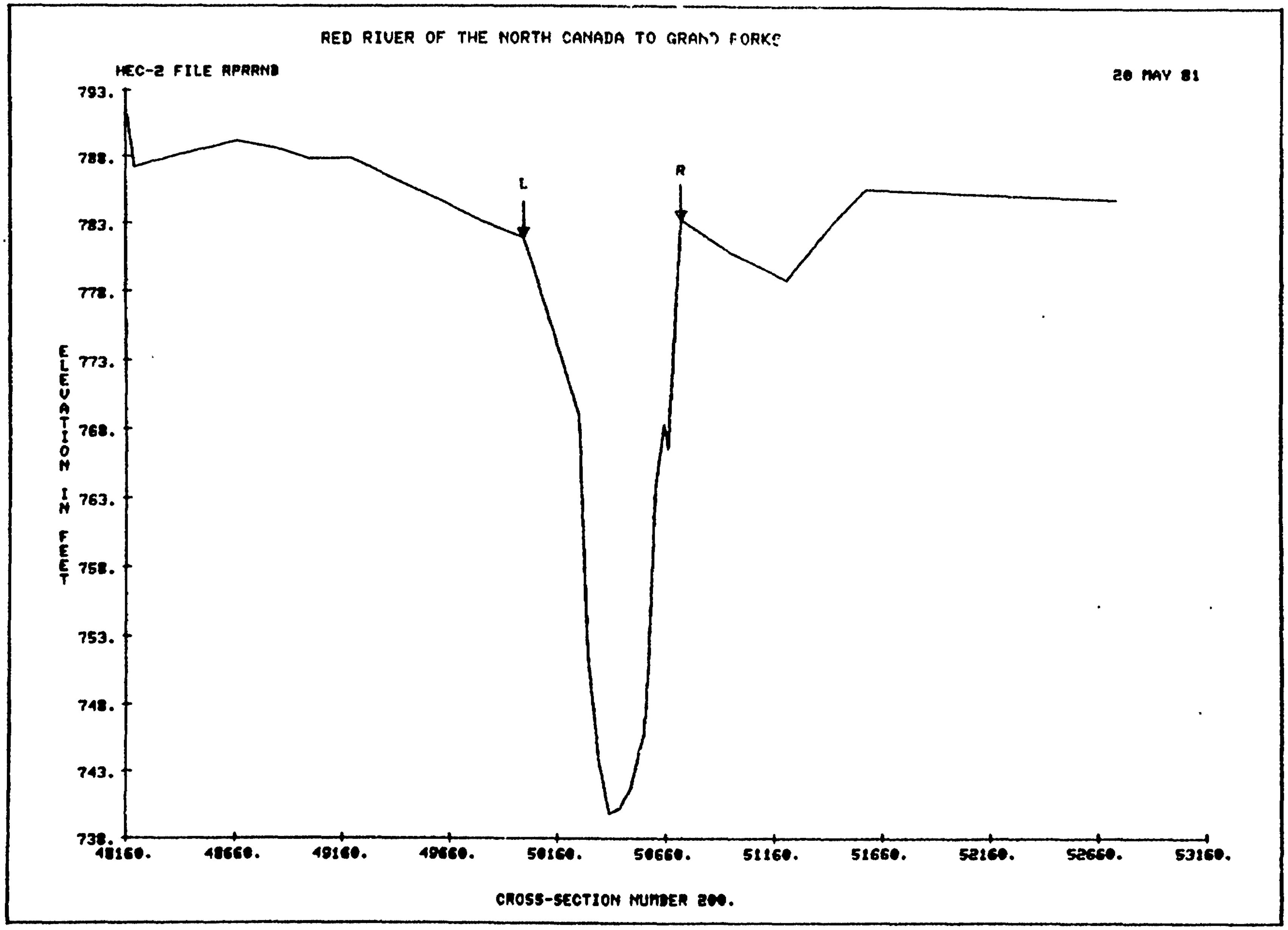
RED RIVER OF THE NORTH CANADA TO GRAND FORKS
HEC-2 FILE RPRRNB
20 MAY 81
L
R
ELEVATION IN FEET
793.
788.
783.
778.
773.
768.
763.
758.
753.
748.
743.
738.
48160.
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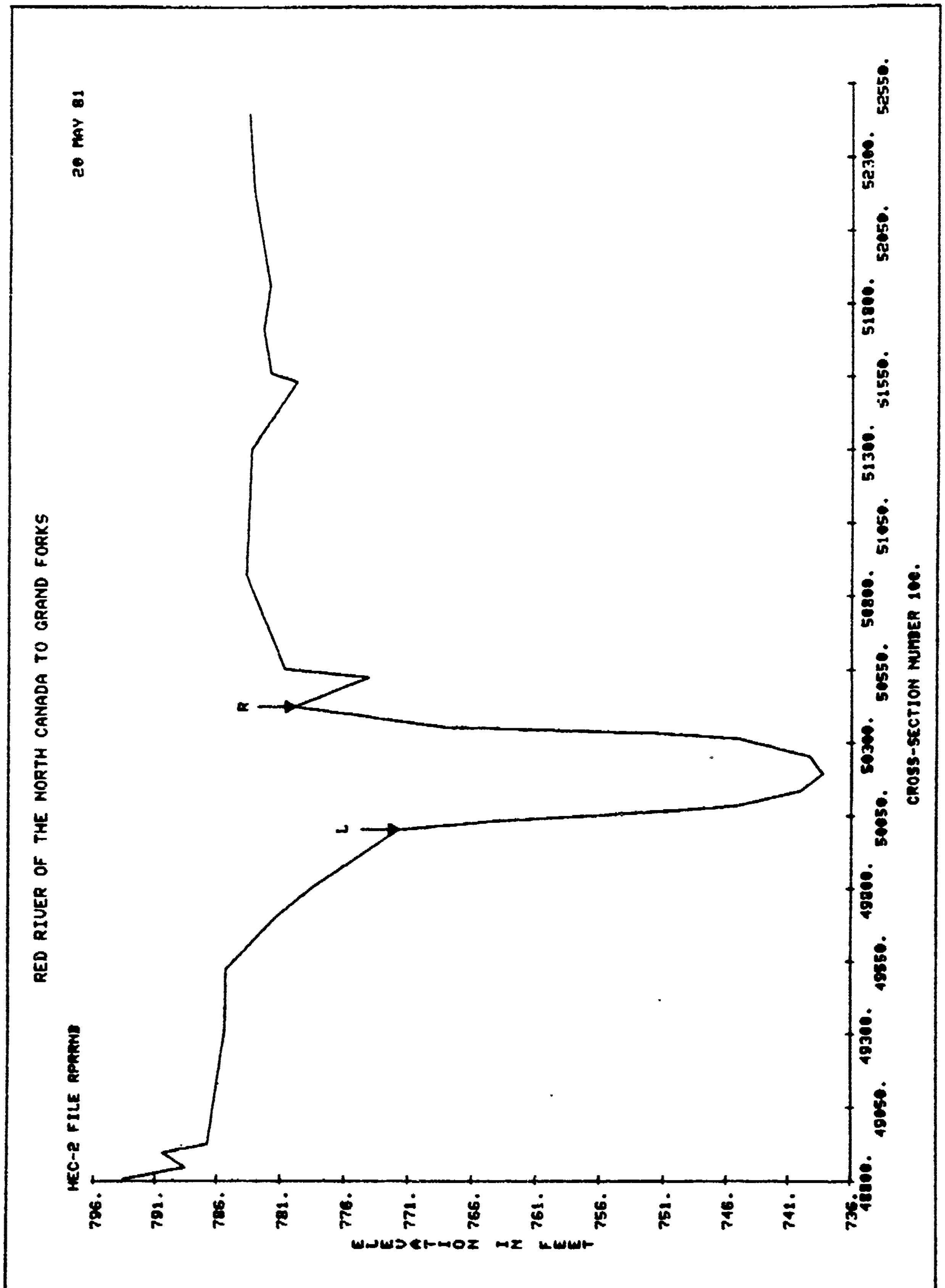
CROSS-SECTION NUMBER 200.


RED RIVER OF THE NORTH CANADA TO GRAND FORKS
20 MAY 81
HEC-2 FILE RPRRNB
ELEVATION IN FEET
CROSS-SECTION NUMBER 100.
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781.
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771.
766.
761.
756.
751.
746.
741.
736.
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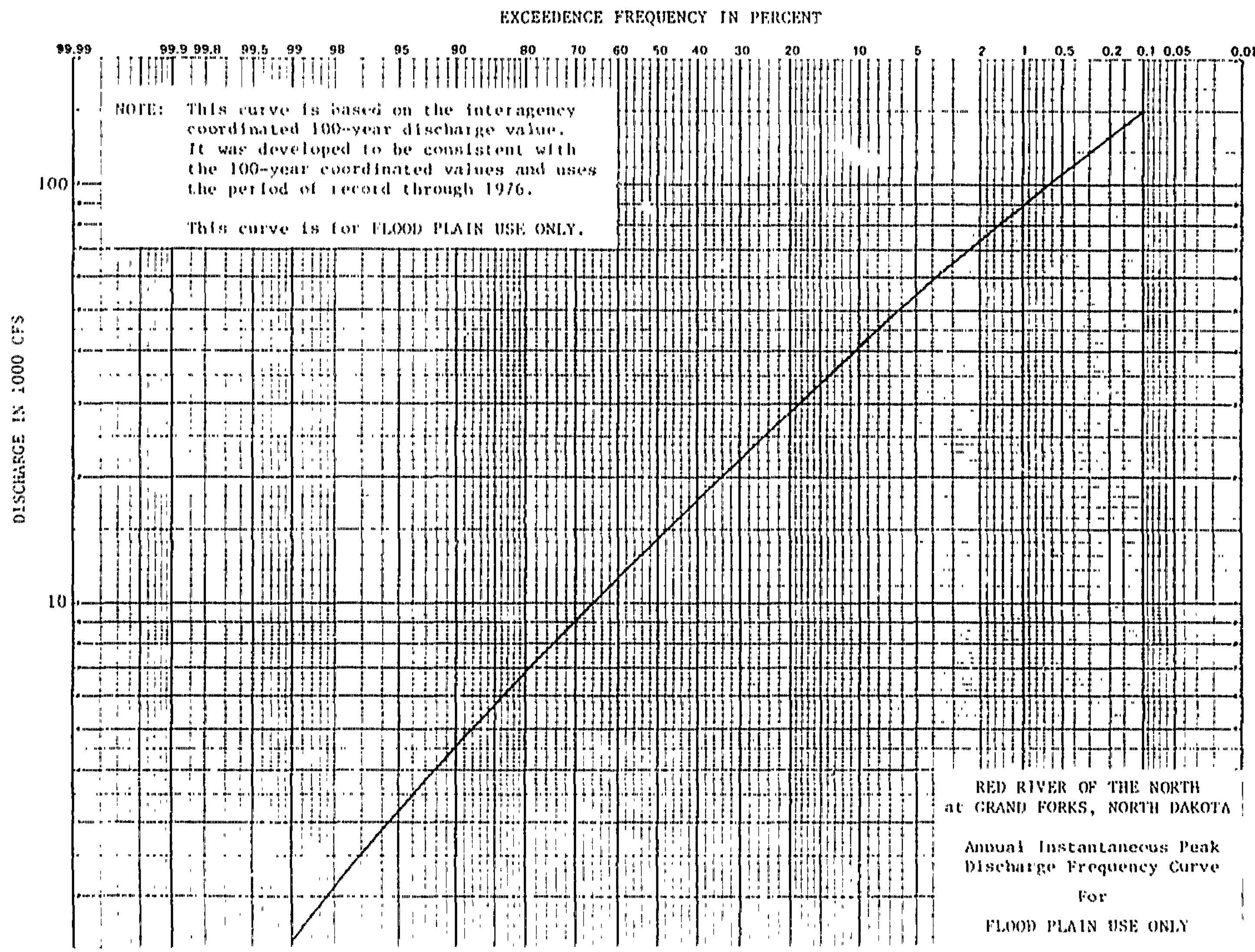
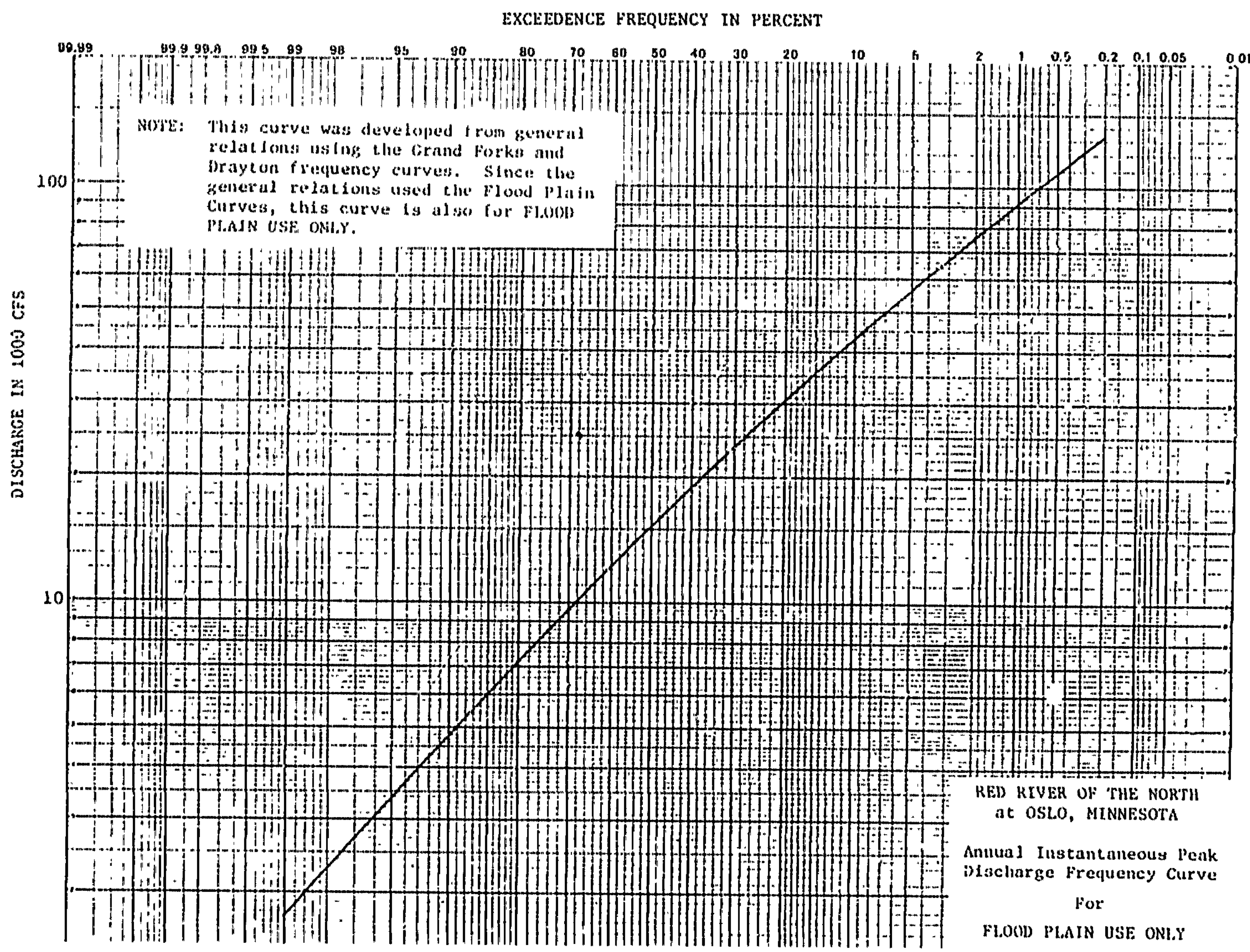
49300.
49550.
49800.
50050.
50300.
50550.
50800.
51050.
51300.
51550.
51800.
52050.
52300.
52550.
L
R

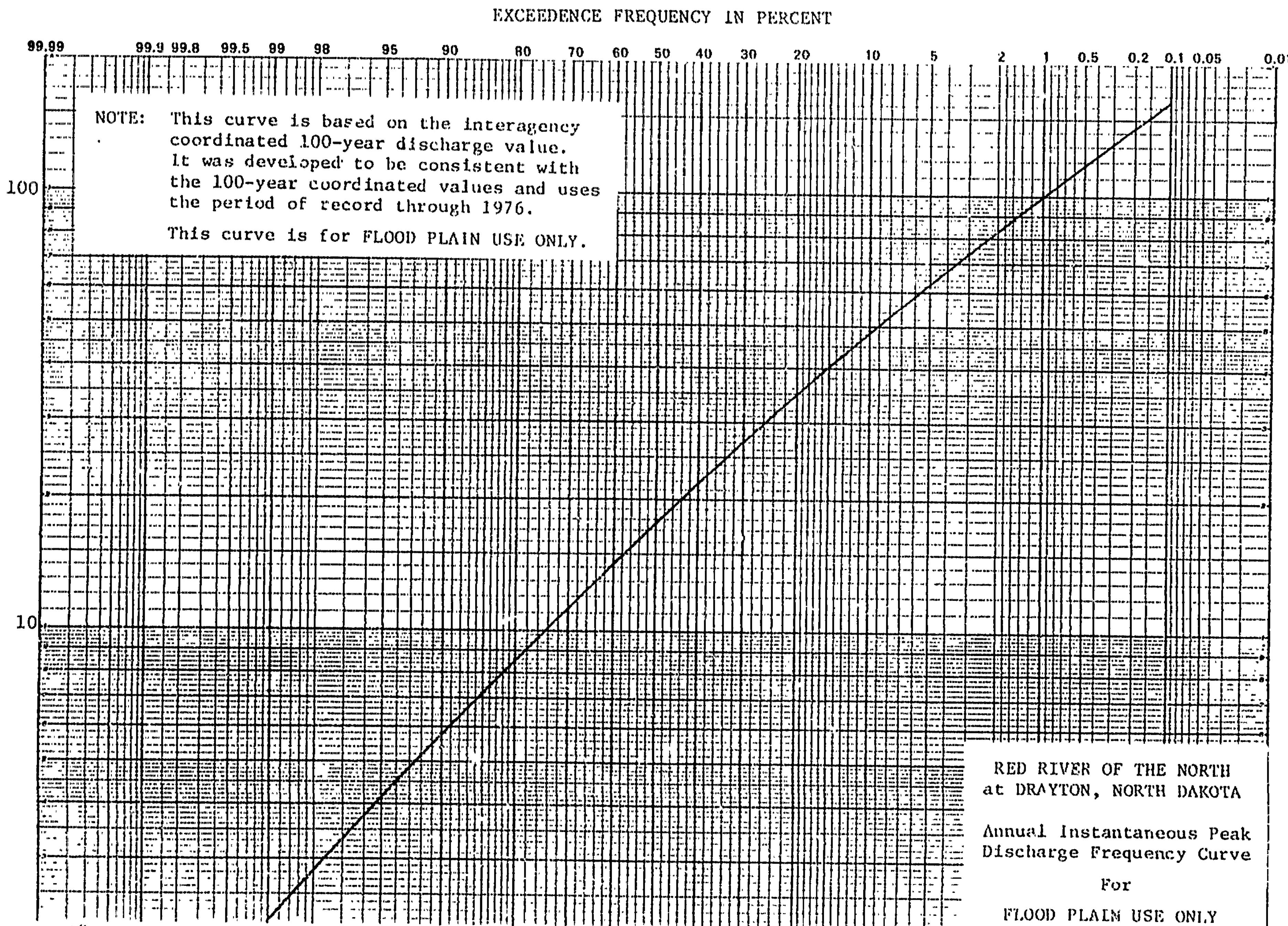
APPENDIX B

FREQUENCY CURVES

Table of discharge values
for various points along the
Red River main stem is being revised and will
be furnished at a later date.


EXCEEDENCE FREQUENCY IN PERCENT
99.99 99.9 99.8 99.5 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
DISCHARGE IN 1000 CFS
100
10
NOTE: This curve is based on the interagency coordinated 100-year discharge value. It was developed to be consistent with the 100-year coordinated values and uses the period of record through 1976.
This curve is for FLOOD PLAIN USE ONLY.
RED RIVER OF THE NORTH
at GRAND FORKS, NORTH DAKOTA
Annual Instantaneous Peak
Discharge Frequency Curve
For
FLOOD PLAIN USE ONLY


EXCEEDENCE FREQUENCY IN PERCENT
99.99 99.9 99.8 99.5 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
DISCHARGE IN 1000 CFS
100
10
NOTE: This curve was developed from general relations using the Grand Forks and Drayton frequency curves. Since the general relations used the Flood Plain Curves, this curve is also for FLOOD PLAIN USE ONLY.
RED RIVER OF THE NORTH
at OSLO, MINNESOTA
Annual Instantaneous Peak
Discharge Frequency Curve
For
FLOOD PLAIN USE ONLY



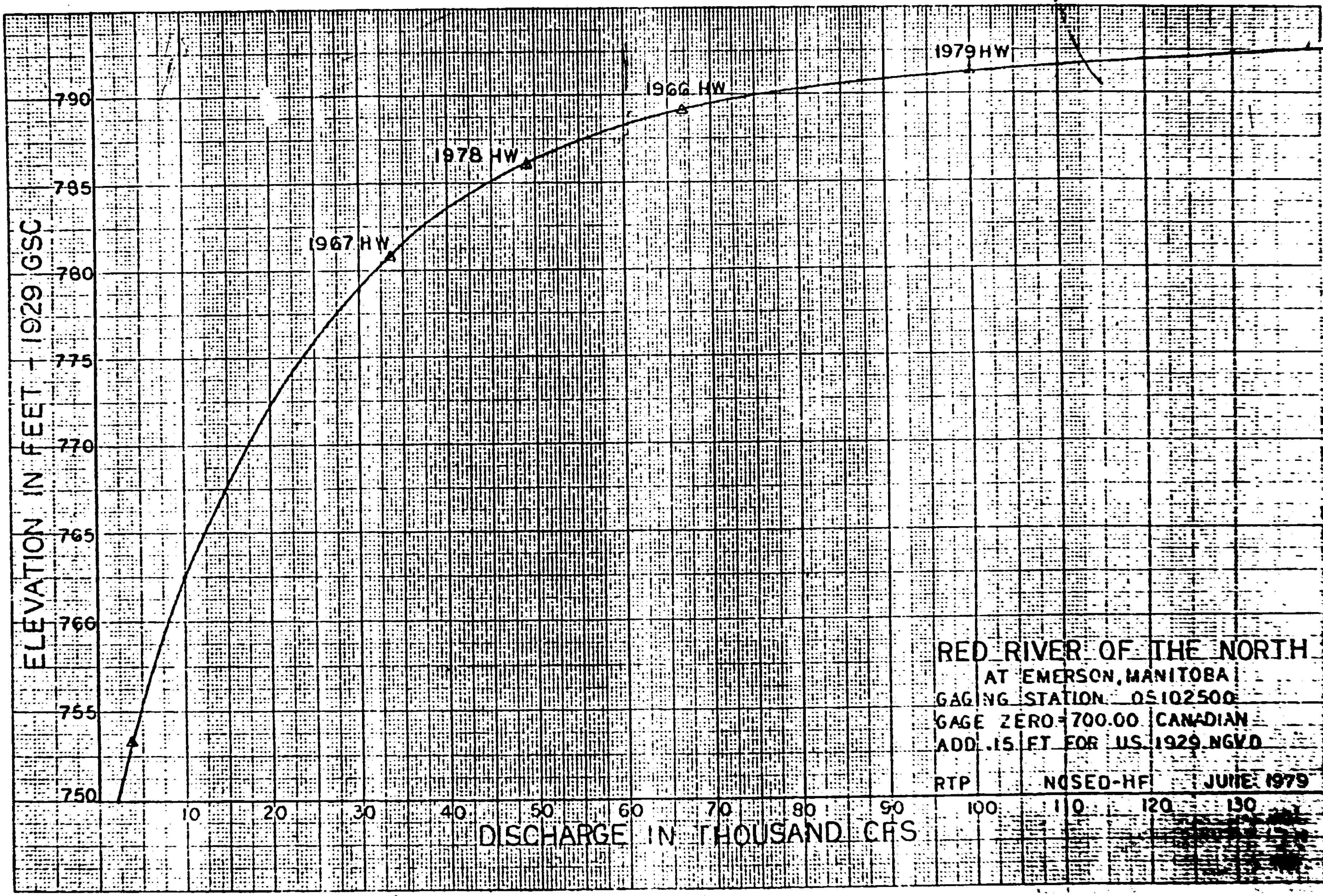
EXCEEDENCE FREQUENCY IN PERCENT
99.99
99.9 99.8
99.5
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1 0.05
0.01
100
10
DISCHARGE IN 1000 CFS
NOTE: This curve is based on the interagency coordinated 100-year discharge value. It was developed to be consistent with the 100-year coordinated values and uses the period of record through 1976.
This curve is for FLOOD PLAIN USE ONLY.
RED RIVER OF THE NORTH
at DRAYTON, NORTH DAKOTA
Annual Instantaneous Peak
Discharge Frequency Curve
For
FLOOD PLAIN USE ONLY

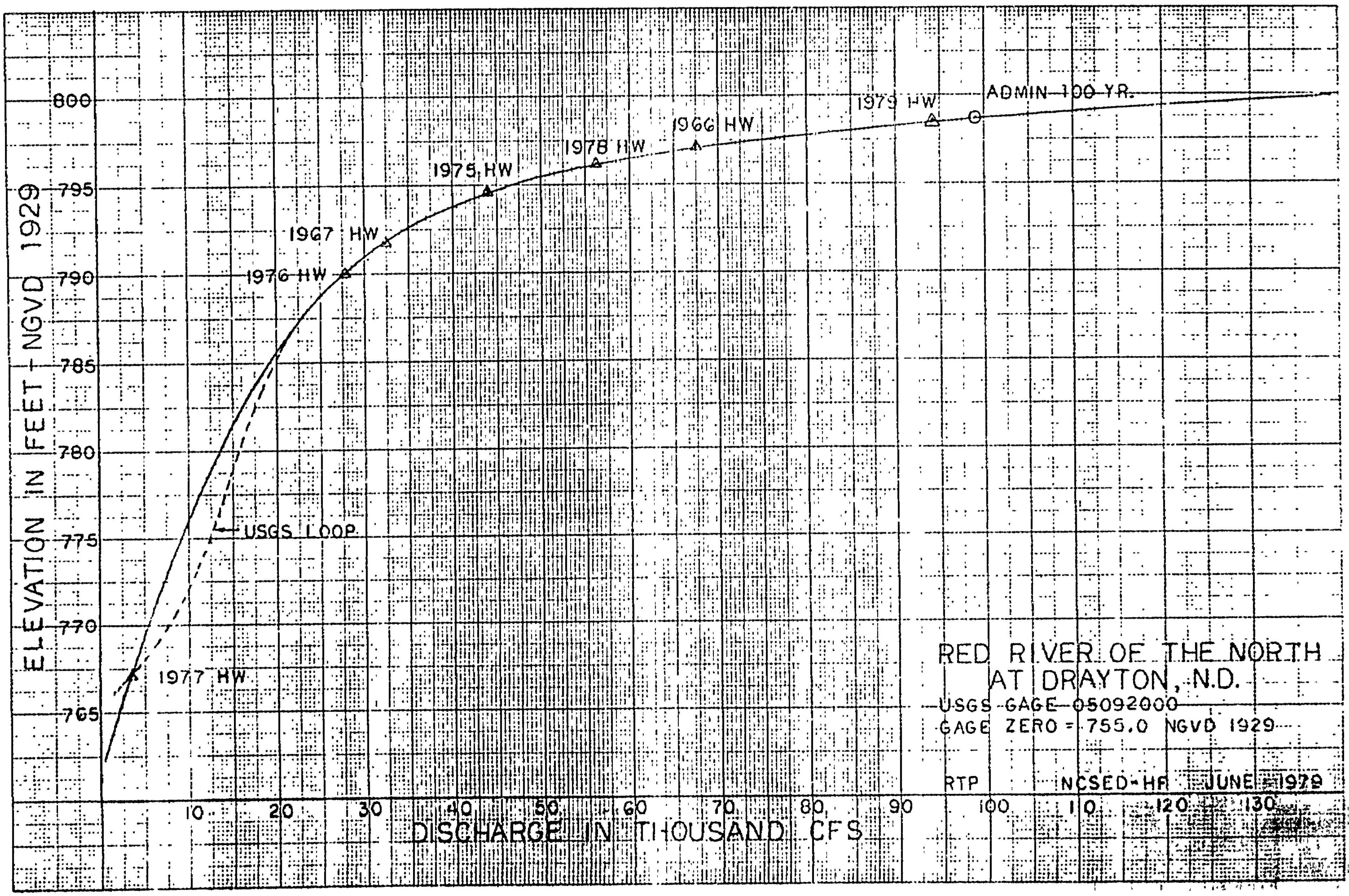
Annual Instantaneous Peak
Discharge Frequency Curve
for
Red River of the North
at Emerson, Manitoba

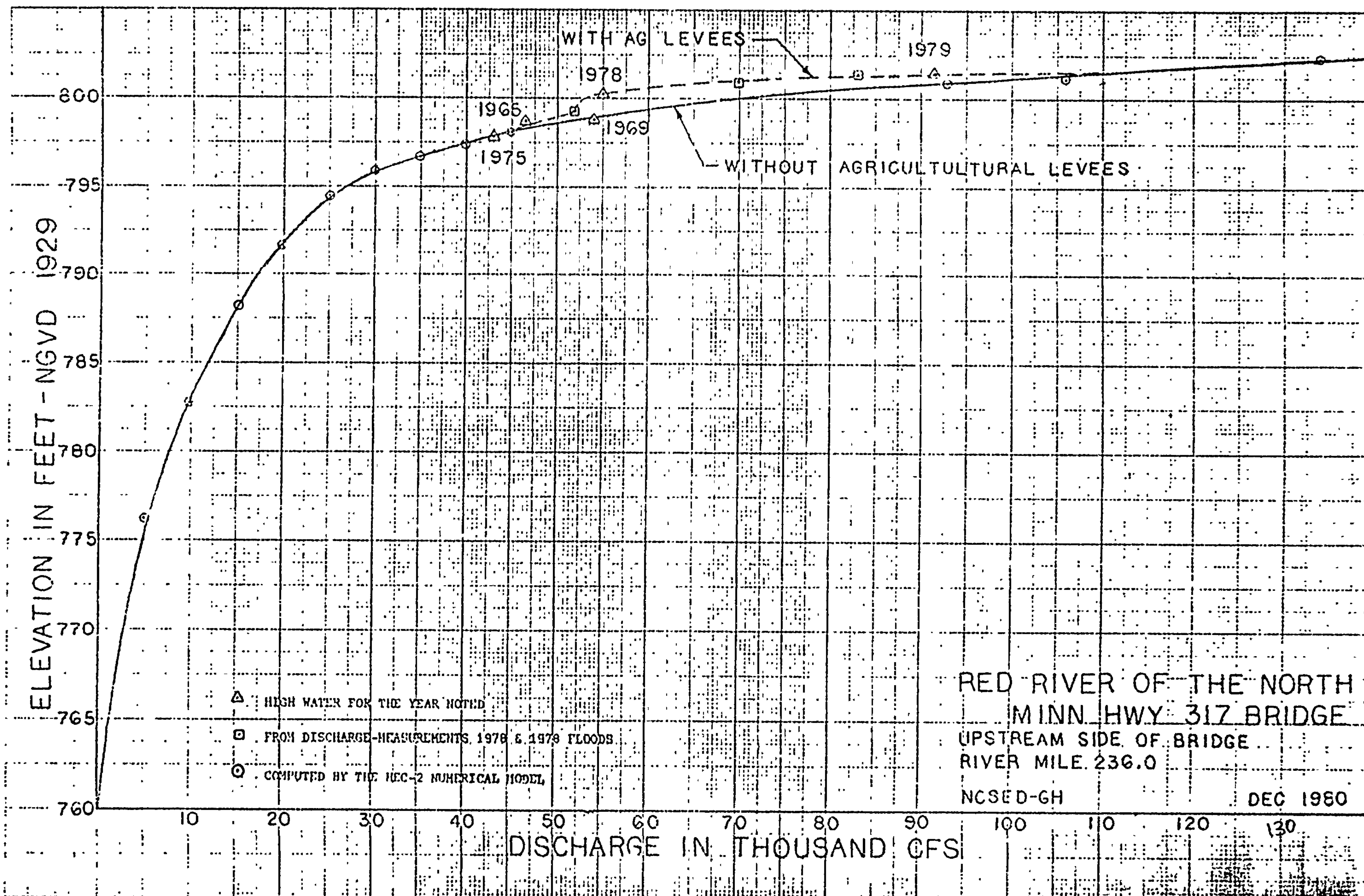
Under revision - will be
provided at a later date.

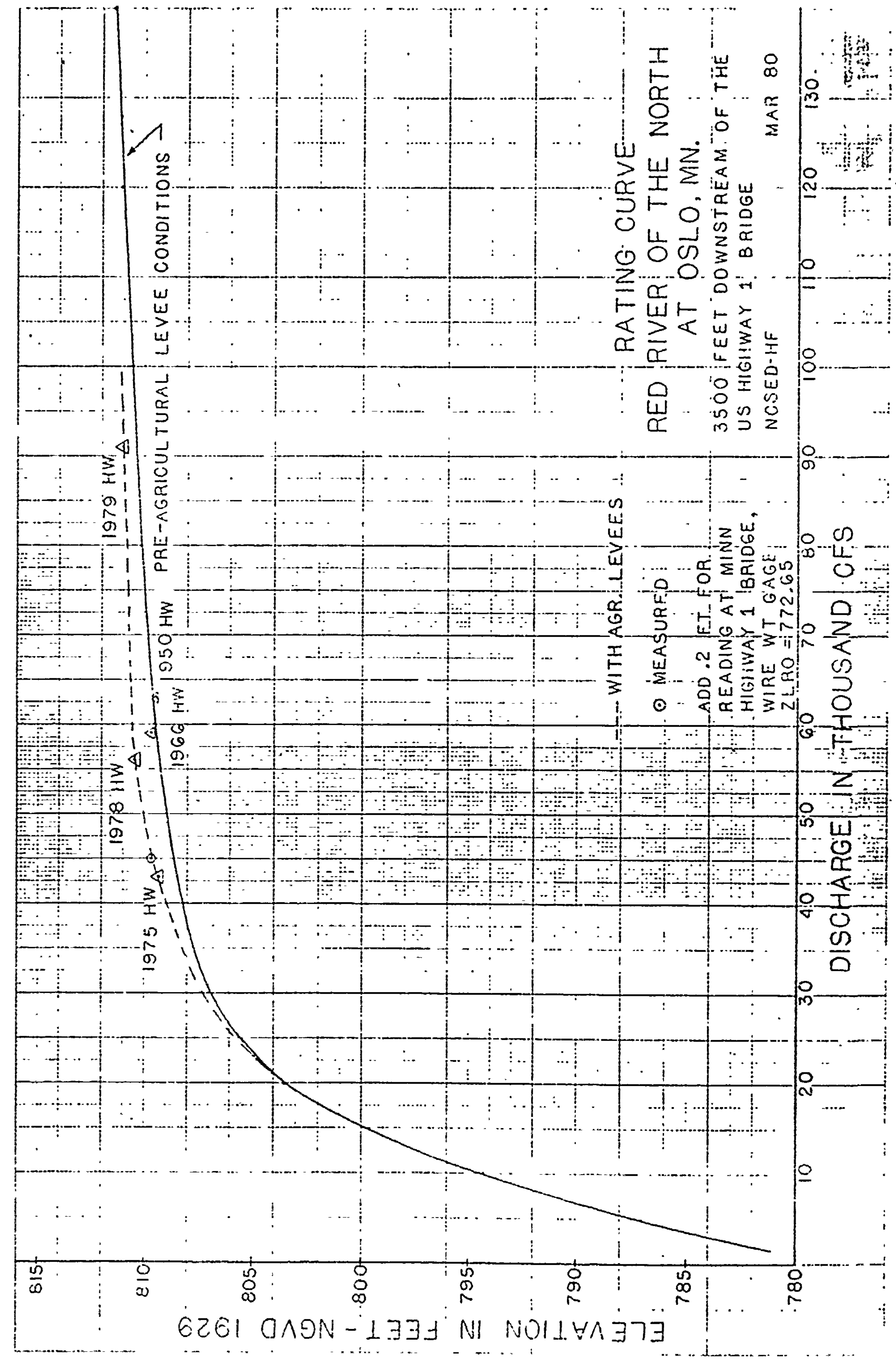
APPENDIX C

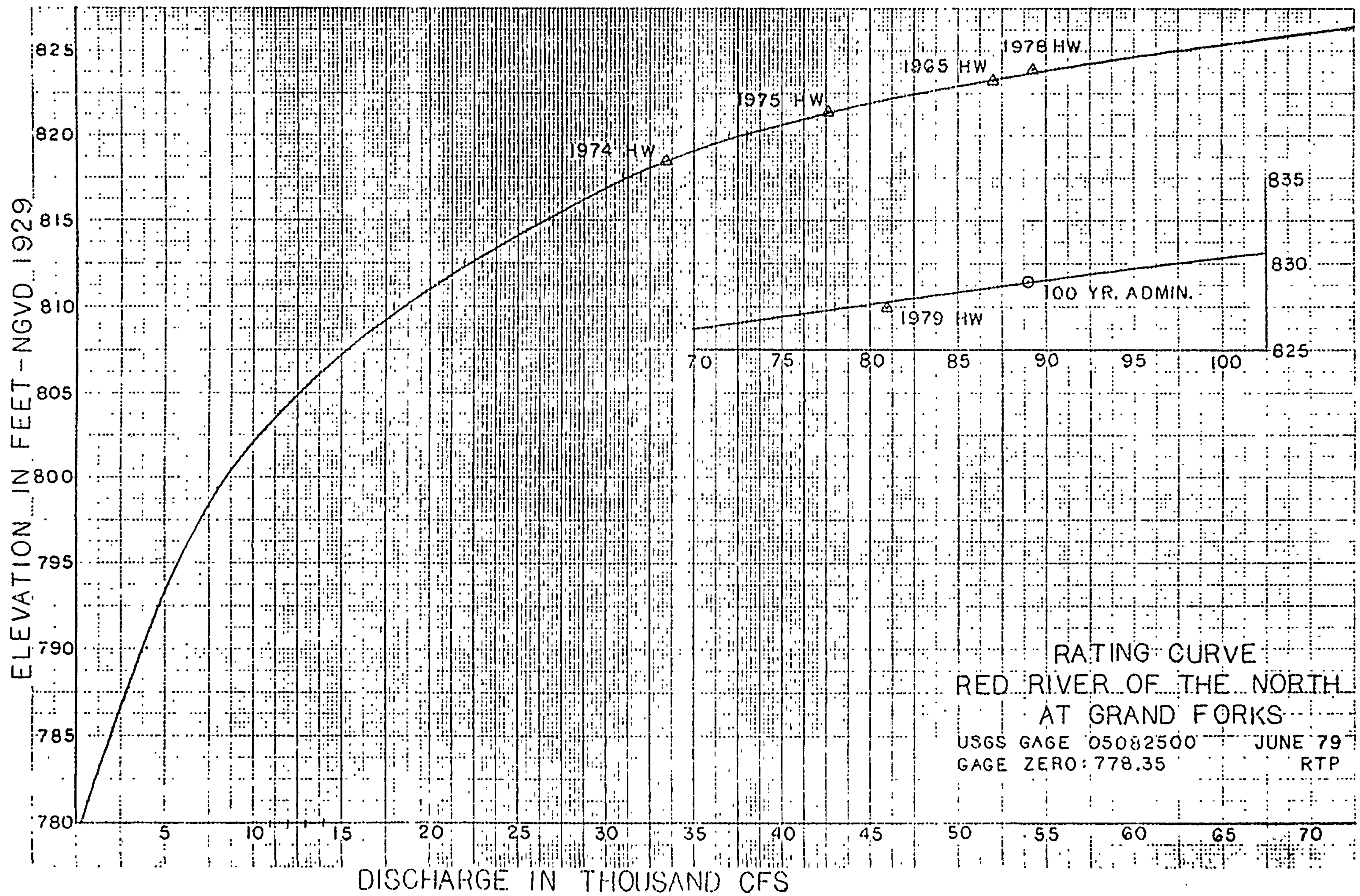
RATING CURVES


RED RIVER OF THE NORTH
AT EMERSON, MANITOBA
GAGING STATION 05102500
GAGE ZERO=700.00 CANADIAN
ADD .15 FT FOR US 1929 NGVD
RTP
NCSED-HF
JUNE 1979
ELEVATION IN FEET - 1929 GSC
DISCHARGE IN THOUSAND CFS
1979 HW
1966 HW
1978 HW
1967 HW
790
785
780
775
770
765
760
755
750
10
20
30
40
50
60
70
80
90
100
110
120
130


RED RIVER OF THE NORTH
AT DRAYTON, N.D.
USGS GAGE 05092000
GAGE ZERO = 755.0 NGVD 1929
RTP
NCSED-HR
JUNE 1979
ELEVATION IN FEET - NGVD 1929
DISCHARGE IN THOUSAND CFS
800
795
790
785
780
775
770
765
10
20
30
40
50
60
70
80
90
100
110
120
130
ADMIN 100 YR.
1979 HW
1966 HW
1978 HW
1975 HW
1967 HW
1976 HW
USGS LOOP
1977 HW


RED RIVER OF THE NORTH
MINN HWY 317 BRIDGE
UPSTREAM SIDE OF BRIDGE
RIVER MILE 236.0
NCSED-GH
DEC 1980
WITH AG LEVEES
WITHOUT AGRICULTULTURAL LEVEES
1965
1969
1975
1978
1979
△ HIGH WATER FOR THE YEAR NOTED
⊡ FROM DISCHARGE-MEASUREMENTS, 1978 & 1979 FLOODS
⊙ COMPUTED BY THE HEC-2 NUMERICAL MODEL
ELEVATION IN FEET-NGVD 1929
DISCHARGE IN THOUSAND CFS
760
765
770
775
780
785
790
795
800
10
20
30
40
50
60
70
80
90
100
110
120
130


RATING CURVE
RED RIVER OF THE NORTH
AT OSLO, MN.
3500 FEET DOWNSTREAM OF THE
US HIGHWAY 1 BRIDGE
NCSED-HF
MAR 80
PRE-AGRICULTURAL LEVEE CONDITIONS
WITH AGR. LEVEES
⊙ MEASURED
ADD .2 FT. FOR
READING AT MINN
HIGHWAY 1 BRIDGE,
WIRE WT GAGE
ZERO = 772.65
1979 HW
1978 HW
1975 HW
1966 HW
1950 HW
DISCHARGE IN THOUSAND CFS
10
20
30
40
50
60
70
80
90
100
110
120
130
ELEVATION IN FEET - NGVD 1929
780
785
790
795
800
805
810
815


RATING CURVE
RED RIVER OF THE NORTH
AT GRAND FORKS
USGS GAGE 05082500
JUNE 79
GAGE ZERO: 778.35
RTP
1974 HW
1975 HW
1965 HW
1978 HW
1979 HW
100 YR. ADMIN.
ELEVATION IN FEET-NGVD 1929
DISCHARGE IN THOUSAND CFS

APPENDIX D

STATES' CRITERIA ON AGRICULTURAL LEVEES

FIRST AMENDMENT TO

JOINT AND COOPERATIVE AGREEMENT
FOR THE ESTABLISHMENT OF CRITERIA
FOR AUTHORIZING DIKES AND OTHER
FLOOD CONTROL STRUCTURES AND MEASURES
ON THE RED RIVER OF THE NORTH
AND THE BOIS DE SIOUX RIVER

1. Article II of the agreement is hereby amended by adding the following paragraph:

II. INTENT OF AGREEMENT

The intent of this agreement is to provide for total and comprehensive water management of the entire Red River Basin. Comprehensive water management includes both structural and nonstructural measures and requires involvement and participation at all levels of government. This agreement ensures that both states will provide for uniform and consistent flood plain management along the Red River of the North and Bois De Sioux River and that both states are totally committed to long-range water management objectives over the entire Red River watershed.

2. Article IV of the agreement is hereby amended by the deletion of the existing article and the insertion of the following new article:

IV. JOINT DIKE CRITERIA FOR AGRICULTURAL DIKE CONSTRUCTION

A. GENERAL PURPOSE

The purpose of these criteria is to provide for the orderly and consistent review of permit applications to construct, relocate, rebuild or alter agricultural dikes along the Red River of the North and Bois de Sioux Rivers in order to assure that the granting of such permits would be in the best interests of the people of Minnesota and North Dakota. These criteria would be mutually applicable in both states. The authority to establish these joint criteria is granted to the Commissioner of Natural Resources in Minnesota Statutes, Sections 105.42, 105.49

and 471.59 and to the North Dakota State Engineer in Section 61-02-24 and 61-16-15 of the North Dakota Century Code. The two states recognize that establishment of these criteria governing the issuance, review and denial of permits to construct, relocate, rebuild or alter agricultural dikes along the boundary rivers is but the <u>first</u> step in the exercise of joint control over those activities which could contribute to an increased flood potential of these rivers. The two states further recognize the need to exercise this joint control because local or state water management decisions may have an interstate and international impact.

The criteria herein are being established at this time because there is a current need to provide a basis for the review of existing, unauthorized agricultural dikes and permit applications for the construction of additional agricultural dikes along the boundary waters. Local land owners view such dikes as interim solutions to local flood problems.

It is intended that each state will use these criteria for the adoption of regulations in each respective state.

B. JURISDICTION

These criteria governing the review, issuance and denial of permits to construct, relocate, rebuild or alter agricultural dikes along the boundary rivers pertain to all such dikes located within the flood plains of the Red River of the North and the Bois de Sioux Rivers. Floodplain areas of the Red River of the North are defined by Appendix O, Volume 8 of the Souris-Red-Rainy Basin's Comprehensive Study as "Red River of the North Main Stem Regional Floodplain Area" and the floodplain of the Bois de Sioux River is defined by the U.S. Geological Survey one percent chance of recurrence area flood quadrangles. These criteria apply to dikes constructed on tributaries within the floodplains of these boundary rivers.

C. DEFINITIONS

For the purposes of these regulations certain terms or words used herein shall be interpreted as follows:

"Dike" means an embankment constructed of earth and/or other suitable materials to protect agricultural lands from floods which result from overflow of watercourses or from diffused surface waters.

"Boundary Rivers" means the Red River of the North and the Bois de Sioux River as they form a natural boundary between the States of Minnesota and North Dakota.

"Farmstead" means a farm dwelling and/or associated farm buildings.

"Flood Frequency" means the average frequency, statistically determined, for which it is expected that a specific flood stage or discharge may be equalled or exceeded. This frequency is usually expressed as having a probability of occurring, on the average, once within a specified number of years.

"Flood Waters" means those waters which temporarily inundate normally dry areas adjoining a watercourse. This inundation results from an overflow of the watercourse caused by excessive amounts of rainfall and/or snowmelt which exceed its capacity.

"Public Waters" means all natural and altered natural watercourses with a total drainage area greater than two square miles, except that trout streams officially designated by the Commissioner shall be public waters regardless of size of their drainage area.

"Ring Dike" means an embankment constructed of earth and/or other suitable materials for purposes of enclosing a farmstead.

"Watercourse" means a channel in which a flow of water occurs either continuously or intermittently in a definite direction. The term applies to either natural or artificially constructed channels.

D. SEVERABILITY

The provisions of these criteria shall be severable, and the invalidity of any paragraph, subparagraph, or subdivision thereof shall not make void any other paragraph, subparagraph, subdivision, or any other part.

E. DESIGN CRITERIA

1. Dikes are to be constructed at a location and elevation so as not to cause an increase in elevation of the 100-year frequency flood of more than one-half foot at any point along the river. Calculations of the effects of the dikes shall be based on total and equal degree of encroachment along both sides of the river. Dikes shall not cause

an increase in the elevation of flood waters which will result in an unreasonable increase in flood damages due to the displacement of flood waters.

2. Calculation of the effects of proposed dikes shall be based on the dikes being located on both sides of the Red and Bois de Sioux Rivers so as not to cause more than one-half of the maximum allowable stage increase. If mutual agreement has been reached between persons on both sides of the river, dikes on one side of the river may utilize the entire increase in flood stage elevation allowable.

3. Dike Dimensions. Dike top width shall not be less than six (6) feet. Side slopes shall not be steeper than 3:1, except where slope stability analysis and slope erosion control can justify steeper slopes. No organic soil or material shall be allowed in the foundation of the fill of dikes.

4. Vegetative Cover and Riprap. A protective cover of grasses shall be established on all exposed surfaces of the dike. Riprap shall be used where required for control of erosion.

5. Interior Drainage. Dikes shall have provisions for interior drainage. The design shall include plans to handle the discharge from the drainage area based on drainage design requirements for the local area.

F. HYDROLOGIC DATA FOR DESIGN

The North Dakota State Water Commission and the Minnesota Department of Natural Resources shall provide the discharges and corresponding elevations of frequently occurring floods (and other available flood data) for use in dike design.

G. DIKES ACROSS NATURAL WATERWAYS AND LEGAL DRAINS

Dikes shall not be constructed across public watercourses in Minnesota or watercourses in North Dakota as defined by 61-01-07 of the North Dakota Century Code, without the proper authorization by the appropriate state agency. Dike setbacks along tributary waterways, within the area defined in Section B of these criteria, to the boundary water shall meet the criteria as stated in Section E.

Dikes constructed across legal drains or public ditch systems shall require the approval of the appropriate watershed district, drain board, water management district or other local authority.

H. FARMSTEAD DIKING

Within an existing dike system, ring dikes around individual farmsteads shall not require dike permits if they are not provided with tie-backs to existing roadways or dikes. Ring dikes provided with tie-backs shall be considered part of the overall dike system and will be required to secure diking permits. However, approvals must be made from local authorities where applicable.

I. ADMINISTRATION

1. Application for Permits. All applications submitted by the owner to construct, to relocate, rebuild or alter dikes shall be made on forms provided by the Minnesota DNR or ND State Engineer and shall be accompanied by two (2) complete sets of plans and specifications. Such plans and specifications shall include the following:

a) A general location map within a minimum scale of 1"=800' showing the following:

1) Location of the dike with respect to the watercourse.

2) Location of field inlets to provide for internal drainage.

3) Location of legal drains and natural channels tributary to the main river channel.

b) Detailed cross-sections of the dike showing elevations, in relation to mean sea level, and side slopes.

c) Any other information deemed necessary by the permitting agency in order to adequately process the permit.

After review of the information required above and other available data, the state agency to which the application is made shall determine the location and number of required cross-sections of the river channel and overland areas. These locations shall be provided to the applicant who shall then provide the required cross-section data. The applicant shall undertake and agree to pay the expenses incurred in securing these cross-sections.

2. Joint Permit Applications. Joint permit applications involving two or more landowners or a permit application on behalf of two or more landowners will be accepted by the State agencies. These permit applications, taken together, must meet the regulations adopated by each agency.

3. Issuance of Permits. Dike permits will be issued only upon concurrent approval by the state and local government in which state the dikes are located. Approval of the permit will in no way relieve the owner from damages which may be caused or created by construction of the dikes.

4. Joint Administration. A copy of each application and accompanying information for a permit shall be forwarded by the state agency receiving the initial application to the other state for comment and recommendation before final approval is granted. Comments shall be returned within thirty (30) days after receipt in order to be considered.

5. Permit Revocation. The applicant shall provide for certification by a registered land surveyor, engineer, or other qualified person or agency that the finished dike elevations are not higher than those approved by the state agency to which the application was submitted.

The permit shall be revoked for failure to construct the dike in accordance with the plans and specifications submitted. Structural alteration of the dike without permission of the appropriate state agency will also result in having the permit revoked.

6. Reconstruction. Reconstruction or rebuilding of any authorized dikes shall require notification of the state agency in which state the proposed activity is located, and recertification in accordance with these criteria.

J. EXCEPTION TO THE CRITERIA

Under special circumstances, exceptions to the dike criteria may be authorized on an individual basis but they must have the concurrent approval of the North

Dakota State Engineer, local water management board in North Dakota, Minnesota Department of Natural Resources and local watershed district in Minnesota. Factors that will be considered, among other things, shall be increase in flood stage, increase of stage at existing city dike, increase in stream velocity and environmental effects. In addition, for the purpose of flexibility, each state shall consider the utilization of farmsteads, property lines, and existing roads when evaluating applications on dike construction, consistent with these criteria.

K. APPLICATION TO EXISTING DIKES

1. Application to Existing Dikes. These criteria shall apply to all unauthorize dikes constructed in the past for the protection of those agricultural lands located within the flood plains of the Red River of the North and the Bois de Sioux, as defined in Article IV, Section B of this agreement. Exceptions are farmstead dikes if they meet the provisions of Article IV, Section H of this agreement.

2. Evaluation of Existing Dikes. Parties to this agreement agree to take coordinative and direct action to evaluate all unauthorized dikes constructed in the past for the purpose of bringing them into compliance with either Section E or Section J of the dike criteria. The procedure for evaluation of existing dikes shall be mutually agreed to by the State Water Commission and the Department of Natural Resources after consultation with the local water management agencies in the floodplain. The State Water Commission and the Department of Natural Resources shall provide to the local water management agencies in the floodplain area all necessary data gathered from the evaluation of existing dikes.

3. Corrective Plans. The local water management agencies shall utilize the technical assistance provided by the State Water Commission and the Department of Natural Resources, and in consultation with the affected property owners, expeditiously develop a corrective plan that will mitigate to the maximum extent

possible the adverse impacts to the floodplain and will be in compliance or substantial compliance with the adopted criteria. The corrective plan shall include, among other things, an implementation schedule. Factors that will be considered, among other things, in the development of the corrective plan shall be increase in flood stage, increase of flood stage at existing city dikes, increase in stream velocity, environmental effects, utilization of farmsteads, property lines, existing roads, cost of dike modifications, and the amount of the reduction of the adverse impact in the floodplain that can be achieved in a reasonable manner.

4. Approval of Corrective Plan. The corrective plan shall then be submitted to the State Water Commission or the Department of Natural Resources for approval. Those portions of the corrective plan which are in compliance with Section E of the dike criteria shall be approved accordingly. Those portions of the corrective plan which are not in compliance with Section E of the dike criteria shall be governed by Section J.

5. Enforcement. If the responsible party or parties do not bring the unauthorized dike or dikes constructed in the past into conformance in accordance with the approved corrective plan, the State of North Dakota and the State of Minnesota shall act independently or jointly to secure such conformance, exercising applicable federal and state laws. Any such actions shall be coordinate· the maximum extent.

In furtherance of this section, Article V of the original agreement is hereby deleted.

3. A new Article V of the agreement is hereby created:

V. URBAN AND MUNICIPAL DIKES

A. Previous sections of this agreement address only agricultural and rural dikes. However, another important step in the process of joint and comprehensive water management of the Red River is to develop diking criteria for urban and

municipal areas which will have uniform application on both sides of the Red River. Therefore the parties hereby agree, in conjunction with and in cooperation with local water management officials and appropriate municipalities, to adopt mutually applicable criteria for the approval of dike construction along the Red River of the North and the Bois de Sioux in the urban and municipal areas in both states. Such criteria may include designation of a floodplain and floodway and specifications for maximum dike elevations.

B. Such criteria shall be adopted after joint public meetings convened at a mutually acceptable place and time. The parties hereby further agree, if necessary, to request technical assistance and recommendations from the appropriate federal agencies, including the United States Army Corps of Engineers, the Soil Conservation Service, and Federal Emergency Management Agency.

C. The adopted criteria may be substantially altered or amended by mutual agreement of the parties in writing.

This document paid for with State funds

STATE OF MINNESOTA	STATE OF NORTH DAKOTA
Albert H. Quie	Arthur A. Link
Albert H. Quie Governor	Arthur A. Link Governor
DATE: 2/22/80	DATE: 2-6-80
Commissioner Department of Natural Resources	State Engineer State Water Commission
DATE: 2/21/80	DATE: 2-8-80

APPENDIX E

RECREATION

ST. PAUL DISTRICT
U. S. ARMY CORPS OF ENGINEERS
1135 U. S. POST OFFICE & CUSTOM HOUSE
ST. PAUL, MINNESOTA 55101

Contract No.:
NCSED-ER-R-1022

ANALYSIS OF PUBLIC USE IMPACTS AND POTENTIALS ASSOCIATED WITH THE RED RIVER OF THE NORTH MAIN STEM FLOOD CONTROL PROJECT

Prepared By:

ROY F. WESTON, INC.
Suite 1860W
332 Minnesota Street
St. Paul, Minnesota 55101
(612) 291-2465

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INTRODUCTION

PURPOSE

The purpose of this report is to identify recreation-related impacts and potentials with the existing and proposed flood control measures in the 140-mile study area along the Red River of the North. The southern limit of the study area is the northern limit of urbanization in Grand Forks, North Dakota and East Grand Forks, Minnesota. The northern limit is the international border between the United States and Canada. The width of the study area coincides with the limit of the 100-year floodplain.

The report is organized to present the recreational facilities currently available in the study area, then to identify areas with potential for development. Also included are recreation-related guidelines for consideration when analyzing levee alignment and design. Maps of the study area (1:24,000 scale) are provided depicting existing potential recreation areas, existing levees and the 100-year floodplain. These, coupled with maps of the study area, conceptual cross sections and cost estimates, present preliminary information concerning recreational potential along the 140 miles of the main stem floodplain.

METHODOLOGY

The study relies on reconnaissance-type methods. Previous studies[1] revealed the names of many of the existing recreation areas. Aerial photographs at a scale of 1:24,000 were examined to locate areas for potential development. These areas were identified on the basis of tree cover, proximity to water, and convenient access. Twenty-two potential sites were identified in this manner. A field reconnaissance narrowed this list to ten sites. Reasons for rejection of some sites included:

- proximity to one or more inhabited residences
- inconvenient or poor quality access roads
- lowlying areas and steep river banks
- insufficient width to permit development.

Data collected from existing studies and photographs, as verified in the field, were plotted on the base maps. These inventory existing recreation opportunities and present sites with the potential for development (1:24,000 scale maps).

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[1]U. S. Army Corps of Engineers, Recreation Sites Under 15 Acres, Red River of the North Basin, 1981.

U. S. Army Corps of Engineers, Red River of the North Reconnaissance Report, Main Stem Subbasin. Final Report, December, 1980.

School athletic fields have been eliminated from consideration in this report. The reason for this is that school atheletic fields serve a very different function from outdoor recreation areas. Their attraction is limited to community residents and to school-aged children. Their appeal is not widespread.

EXISTING RECREATIONAL AREAS

Existing outdoor recreation facilities are limited within the study area. Presently, all but one of the sites are located within the municipalities scattered along the river. The ones that do exist are well maintained and appear to be regularly used for a variety of activities. As stated before, school playgrounds have not been considered in this investigation. Table 1 presents an inventory of existing recreation areas. These same areas are also included on the maps accompanying this report.

TABLE 1
EXISTING RECREATION AREAS

Name	City/County	Activities/Facilities	Map Sheet No.
Minnesota			
Oslo Municipal Park	Oslo/Marshall	Camping (no facilities) Picnicking Picnic Shelter Picnic Tables Large Charcoal Pit Rest Rooms Ball Park	13
North Dakota			
Drayton Municipal Park	Drayton/Pembina	Camping Picnicking Picnic Shelters (3) Picnic Tables Play Area Charcoal Grills Swimming Pool Tennis Courts (2) Rest Rooms Ball Park	7
Drayton Municipal Golf Course	Drayton/Pembina	Golf (9 holes)	7
Pembina Masonic Historic Park	Pembina/Pembina	None	1
Pembina Historic Site	Pembina/Pembina	Picnicking Charcoal Grills Play Area Ball Park	1
Red River Access	Pembina/Pembina	Boat Ramp Fishing	1
Walhalla Golf Course	Pembina/Pembina	Golf (9 holes)	1

(continued)

Red River Access (N.D. WMA)	Drayton/Pembina	Boat Ramp Fishing	Map Sheet No. 6

Camping facilities are available only at Drayton Municipal Park and Oslo Municipal Park. Other than these two locations, the nearest camping is located south of Grand Forks, North Dakota and in Grafton, 10 miles from Interstate Highway 29. The latter site is well out of the 100-year floodplain.

Picnic facilities are somewhat more frequent. Oslo Municipal Park, Drayton Municipal Park, and Pembina Historic Site all provide tables and shelters. Along the entire 140-mile stretch of river, only two boat access point exists. Both are in Pembina County.

It must be noted that opportunities for hunting, birdwatching, fishing, sightseeing and nature study can be found at locations independent of designated recreation areas. The entire study area, therefore, is a recreation resource to some extent.

RECREATION PARTICIPATION

Since the Red River of the North is the boundary between North Dakota and Minnesota, an analysis of recreation participation for the study area must include information from both North Dakota's and Minnesota's State Comprehensive Outdoor Recreation Plans (SCORP). The approach to recreation analysis differs between SCORP's but a synthesis of the information does provide meaningful predictions regarding future participation trends.

The states' recreation analyses are provided on a regional basis. The area of study is contained in North Dakota State Planning Region 4 and Minnesota Development Region 1. The information provided does not allow analysis at a subregional level. Participation projections (base year 1978) for a variety of activities are provided for 1985, 1990 and 1995.

North Dakota Region

Participation estimates and projections (measured in total days) for the ten most popular activities in Region 4 (North Dakota) are presented in Table 2. Region 4 is composed of four counties: Pembina, Walsh, Nelson, Grand Forks.

TABLE 2
TOTAL DAYS OF PARTICIPATION IN NORTH DAKOTA REGION 4

Activity	1978	1980	1985	1990	1995
Bicycling	32.6	34.9	38.7	42.7	43.8
Ice Skating	18.7	20.5	17.5	17.3	15.3
Outdoor Pool Swimming	16.6	15.5	16.9	17.0	16.6
Snowmobiling	14.3	14.7	15.1	16.0	16.0
Golf	14.2	16.3	19.3	21.6	22.1
Sledding	10.9	19.7	10.4	11.6	10.8
Jogging	10.7	10.2	12.3	12.9	12.9
Picnicking	9.8	11.3	[illegible]	15.2	16.2
Fishing	9.7	10.5	[illegible]	12.0	12.6
Beach Swimming	8.0	10.9	14.4	16.7	17.7

Source: North Dakota SCORP 1980 pg. 4-19.

The most popular activity by far in Region 4 is bicycling. The popularity of bicycling is expected to increase through 1995, and will have over twice the participation of any other activity[1]. Golf,

[1] North Dakota SCORP 1980, pg. 4-19.

jogging, picnicking, and beach swimming are also expected to show increases in popularity. Ice skating is the only activity of the ten most popul_r activities in the region to show a projected decrease in participation. Outdoor pool swimming, snowmobiling and sledding will receive fairly constant participation through 1995.

Minnesota Region

Seven counties comprise Minnesota Development Region 1: Kittson, Roseau, Marshall, Pennington, Red Lake, Polk, Norman. Bicycling by far is the most popular activity in the region (Table 3). It receives over twice the participation of any other activity and is projected to maintain its large portion of participation. None of the activities have a large projected increase in popularity. Those that indicate some increase are: snowmobiling, fishing, pleasure driving, picnicking and boating. Slight decreases are predicted for bicycling, swimming, sledding and ice skating.

TABLE 3
RECREATION OCCASIONS ORIGINATING IN MINNESOTA REGION

Activity	1978[1]	1980	1985	1990	1995
Bicycling	146.5	138.6	132.1	138.6	143.8
Snowmobiling	65.1	62.7	65.0	68.9	68.5
Swimming	39.3	37.2	34.2	34.4	36.0
Fishing	37.0	36.6	37.2	38.5	39.4
Base/Soft Ball	33.0	31.5	30.5	32.5	33.0
Pleasure Driving	29.1	29.5	30.8	31.4	31.2
Sledding	24.3	22.4	21.0	22.5	23.1
Picnicking	22.1	21.9	22.6	24.1	24.5
Ice Skating	21.8	20.0	20.1	20.9	20.6
Boating	21.5	21.7	21.5	22.4	23.1

Source: Minnesota SCORP, 1979.

[1]Data provided in the Minnesota SCORP are measured in recreation occasions (one recreation occasion is participation in one activity at any one continuous length of time) and are divided into occasions occuring in Region 1 and occasions originating in the Region. The latter was selected to assess the participation trends of people within the area.

Public wants for the provision of recreation opportunities have been assessed for Region 1. Table 4 shows the percent of the population desiring more opportunity for activities.

Additional camping opportunities was the most requested opportunity by residents in Region 1. Fishing, swimming, snowmobiling and bicycling, also received a relatively large percentage of requests for additional opportunities.

TABLE 4
PERCENT OF THE POPULATION IN REGION 1 DESIRING MORE OPPORTUNITY

Activity	Percent
Camping	22.4
Fishing	18.3
Swimming	17.6
Snowmobiling	16.5
Bicycling	16.5
Hunting	8.3
Tennis	7.1
Downhill Skiing	6.9
Hiking	6.5
Cross Country Skiing	6.0

Source: Minnesota SCORP, 1979

It is interesting that the activities projected to be the most popular are not necessarily those identified as needing more opportunity. Of the activities listed as strongly desired (Table 4) only four -- fishing, swimming, snowmobiling, bicycling appear in the ten most popular activities (Table 3).

Bicycling and snowmobiling are projected to be by far the most popular activites. Camping, fishing and swimming, by comparison, are more strongly desired than bicycling and snowmobiling. This indicates that a lack of opportunities may be suppressing the participation for camping, fishing and swimming as well as other activities that are strongly desired but relatively low in projected participation. More directly, supply of facilities may be influencing participation. Recreation development should be directed towards the more strongly desired activities in the Region.

Interpretation

The findings of the North Dakota SCORP and Minnesota SCORP ar in general agreement. Bicycling, snowmobiling and swimming are the three most popular activities in the area. The North Dakota SCORP trends indicate a general increase in the already popular activities (Table 2). The figures presented in the Minnesota SCORP predicts a leveling of participation in almost all activites originating in the area (Table 3).

Recommendations identified for Region 1 (Minnesota) suggest a stronger emphasis on providing summer, rather than winter activities. Summer activities mentioned as needing more development are: campgrounds, public fishing accesses, swimming beaches and bicycle paths. Winter activities development should focus on snowmobiling, hunting and cross-country skiing.

Recommendations provided in the North Dakota SCORP are on a statewide level. Trail facilities, (particularly for bicycling, snowmobiling and jogging), wintertime facilities and parks and playgrounds are the top facility needs identified.

Caution is necessary when interpreting participation data presented earlier. Analysis of projected participation for the Red River of the Nor[illegible] based on regional data. The two regions used in the anal- y[illegible] [illegible]de much more area than the study area of this project. Apply- [illegible]al level data to a smaller area assumes homogeneity of recrea- [illegible]eds throughout the region. This is seldom the case due to local population concentrations, popularity of certain activities and the supply of facilities. Sensitivity to these intra-regional variations is important to properly provide for recreation needs of the people.

Analysis

The need for more opportunities for trail oriented activities in the Red River area seems apparent. Levee structures, due to their lineality, lend themselves readily as a resource for trail-oriented activities. Acquisition of long, narrow land parcels for public use, is becoming increasingly difficult due to escalating land prices, the many landowners involved and the pressure for keeping valuable land in agriculture. A levee, with flood control its primary purpose, allows trail land acquisition and development to be more appealing and relatively inexpensive.

Water-oriented activities of high popularity in the area can be provided in association with levee construction. Provisions for more popular water-based activities in the area, such as swimming areas, boat/canoe launches and fishing accesses, may be incorporated into a levee design. Development of this type necessitates a location very near the normal shoreline. Alternatively, boat ramps and access roads can be designed so as to minimize operation and maintenance costs in an area of frequent flooding.

Popular recreation opportunities not trail-oriented (e.g., baseball, sledding, ice skating), may be provided where land required for these activites is available. However, there is no clear advantage to develop facilities of this nature in association with levee structures.

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[1]Minnesota SCORP, 1979, p. 4.054.

POTENTIAL RECREATION AREAS

Field reconnaissance and study of aerial photographs reveal ten areas with the potential for development. It is important to consider these sites as indicative of the potential. At this level of detail it is possible that the sites could be moved from one bank to the other or to move them a few miles up or downstream. Preference of the sponsoring body, ease of land acquisition and access are some of the reason that could lead to shifts in location of a specific site.

The paucity of opportunities for water-oriented recreation resulted in an emphasis on boat access. fishing access and camping. It is recognized that development along the Red River of the North needs to consider the special problems associated with frequent flooding.

With these points in mind, ten potential recreation areas have been identified. (Refer to study area maps for exact locations.) These recreations areas are:

1. **Pembina River.** Located approximately six miles west of the I-29 exit at Pembina, North Dakota. The site is somewhat narrow with approximately 11 acres available for development. An access road would be needed for approximately 1/8 miles. Camping, picnicking and a small play area could be accomodated. Access is along the paved highway 55. (Map Sheet No. 1 of 16)

2. This site is located four miles south of Federal Highway 75 in Kittson County, Minnesota. The site covers approximately 5 acres of trees along the right bank of the Red River of the North. The major drawback is that access is over four miles of gravel road. Potential activities or facilities include fishing, camping and a boat ramp. Because of the quality of access, only primative or tent camping is recommended. (Map Sheet No. 1 of 16)

3. North Dakota Highway 5 and Minnesota 175 bridge crossing The site is approximately 3 miles east of I-29. Both banks have potential for development, but the left bank (North Dakota side) offers the best area. The site is approximately 9 acres of large deciduous trees with low undergrowth. The site could be developed for camping (both trailer and tent), picnicking, boat access, fishing, and a play area. Showers could be provided, but floodproofing or construction of a permanent structure within the floodway present severe constraints. (Map Sheet No. 3 of 16)

4. This site is an abandoned farmstead with good tree cover. The site is located approximately 5 miles north of Highway 11 along Highway 7 in Minnesota. The site (approximately 8 acres) could be readily developed for camping, picnicking, fishing and boat access. A small play area would be appropriate. Access is via a gravel road. Therefore, development to accomodate large recreation vehicles is not recommended. (Map Sheet No. 6 of 16)

5. Bridge crossing along Highway 66 in North Dakota and Highway 11 in Minnesota. Paved access roads and proximity to Drayton (1.5 miles) make this site attractive. Approximately two miles north of the site is a low dam which attracts fishermen. The optimum site is north of the highway in North Dakota. Camping (both trailer and tent), picnicking, boat access, fishing and a play area are recommended. Showers could be provided, but floodway delineation and floodproofing offer significant constraints. Approximately 13 acres are available. (Map Sheet No. 7 of 16)

6. Bridge crossing of North Dakota Highway 17 and Minnesota highway 317. Again, the bridge crossing provides excellent all weather access. The optimum site is again north of the highway in North Dakota, (approximately 11 acres) but south of the highway on the Minnesota sides offer possibilities. Because of the access, camping (trailers and tents), picnicking, fishing and boat access and and a play area are recommended. The site is less desireable than site 5 above, only because no towns are nearby. (Map Sheet No. 9 of 16)

7. This location is actually two relatively small pieces of property on either side of the river near Oslo. The location offers opportunity to develop camping facilities (trailers and tent) now absent at Oslo Municipal Park. The Minnesota side (4 acres) is largely open with some trees to the north and is highly suited for camping. The North Dakota side is smaller by comparison (3 acres) and may accomodate a small camping area. A boat ramp could be located on either bank. The proximity of Oslo offers security and services. (Map Sheet No. 13 of 16)

8. This site is a relatively narrow strip of property (approximately 1 acre) along the North Dakota bank about 2 miles south of Oslo. Boat access could be provided even though the banks are somewhat steep at the site. Fishing would likely become important at the site. Several picnic tables could be provided but space is not sufficient for a designated (shelters, grills, etc.). (Map Sheet No. 13 of 16)

9. This site is located along the Grand Marais River in Minnesota. Paved access is via County Road 21 (Polk County). Dense woodlots, approximately 10 feet above the streambed, make this site attractive. The area east of the highway is better suited for recreation development. Camping and picnicking are ideal activities for this area. Showers and a play area may also be provided if warranted. This site covers approximately 14 acres. (Map Sheet No. 16 of 16)

10. Located on the Minnesota bank this site is 2 miles south of Site 9 on Highway 21. Access is via State Highway 220 North from East Grand Forks to County Road 21. A short spur off of County Road 21 leads into the area. The site (approximately 12 acres) is composed of dense tree groves leading to two farmsteads one quarter mile apart. The proximity to East Grand Forks (five miles) makes this site desirable for recreation. However, there is no high ground or scenic vistas. Recreation facilities could be provided if proper consideration is given to floodway delineation and floodproofing.

Boat ramp, camping areas, picnic facilities, showers and a play area are appropriate for this area. (Map Sheet No. 16 of 16)

1. Damage to Recreation Structures
Special care must be taken to flood proof recreation areas, otherwise small items not anchored will be swept away by floodwaters. Further, permanent above-grade structures such as picnic shelters and play equipment trap debris. This can cause water to back up behind the blockage and can cause damage to the structure itself if the force of the water is sufficient. Permanent vault toilets, shower facilities and other subsurface structures could be damaged by a flood-induced rising water table.

Another concern is the effect of permanent structures on the level of floodwaters. Any permanent structure blocks floodwater movement through the valley. When the structure is large enough and when it is located within the effective flow area,[1] the water surface elevation will increase locally because of the blockage. For this reason, the Federal Flood Insurance Program and Corp of Engineers regulations discourage placement of permanent structures in the effective flow area. Consequently, actual design of recreation areas requires consideration of these hydrologic and hydraulic factors.

2. Sediment Deposition and Erosion
During floods large quantities of sediment are deposited on the overbank areas. Erosion can take place in other areas, particularly along the banks. When recreation areas are inundated, operation and maintenance problems are created. Sand, silt, clay and debris deposited on boat ramps, access roads, camping pads and within picnic areas make the facilities unuseable until cleanup is conducted.

Erosion can be anticipated to be greatest nearest the channel and river banks. Thus, boat ramps are particularly susceptible to damage by floodwaters. It should also be remembered that river channels naturally migrate across the floodplain. Over many years, channels can shift considerable distances when cut into soft, erodible sediment. This r ' process leads to erosion of recreation areas that are placed i ne wrong location. Proper location is important and will be the subject of a later section.

3. Vegetation Damage
Extent of damage to vegetation depends on the hardiness of the species. Many types of vegetation will be lost or severly damaged when submerged for extended periods of time. Many plant species will survive short flood durations (several days) and will regenerate by the end of the season.

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[1]The effective flow area is that part of the river channel and overbank area needed to convey the floodwater without a significant increase in elevation. This effective flow area is called the floodway.

In addition, species native to the local floodplains are generally adapted to withstand periodic inundation. Thus, the effect on native species is minimal.

4. Locating Recreation Facilities Where a Need Exists
Activity participation data is supplied on a statewide and regional basis for the Red River of the North area. Demand for activities at the local level may differ substantially with regional demand. Recreation need assessments not sensitive to local use char-acteristics may result in misplaced or inappropriate facilities.

RECREATION-RELATED GUIDELINES

Following is a list of recreation-related guidelines for use when assessing levee alignment and design. The recreation resource concerns stated in the previous section are the base for these guidelines. Where appropriate, references will be made to conceptual illustrations which depict key levee-oriented recreation concepts.

1. Permanent facilities located within the floodway should be flood proof.
   Facilities that can withstand flooding relatively well are poured concrete surfaces. These would include boat ramps, parking areas and bases for picnic shelters (Figure 1). In addition, picnic tables made of concrete and anchored by being set in concrete or bolted down also protect the capital investment. However, concrete and bituminus surfaces are resistent to erosion and relatively easy to clear. Wood picnic tables, on the other hand, float away if not secured to the ground and also are subject to water damage. Certain types of trail surface can also withstand flooding. It should be noted that no structure will survive constant flooding reoccurrences.

2. Temporary (moveable) facilities (Figure 2), should be used if development in a floodway is necessary.
   Items such as picnic tables, small picnic shelters, barbeque grills and portable toilets can be moved when a flood is expected.

3. Locate facilities on protected side of levee (Figure 2).
   This is the easiest solution; flooding of facilities would not be a concern during floods equal to or lower than levee level of protection. However, a design of this nature is often not feasible due to land availability and desired proximity to the water. An alternative is to locate facilities not flood proof on the protected side of the levee with flood proof facilitites in the floodplain. This of course would depend on levee location, height and design.

4. Trails can be located atop a levee (Figure 3).
   A flood proof surface would not be necessary with this design to withstand floods equal to or below the designed level of protection. Trees and dense shrubbery can be planted to minimize wind. Wind breaks are especially important for winter trail use activities.

5. Recreation facilities must be located where the need exists.
   Regional participation and future demand data must be adjusted to meet the local needs and interests. Local planners and managers of recreation facilities can aid in planning appropriate recreation opportunities.

Figure 1

Permanent Structures – Adjacent to Water

Water Oriented

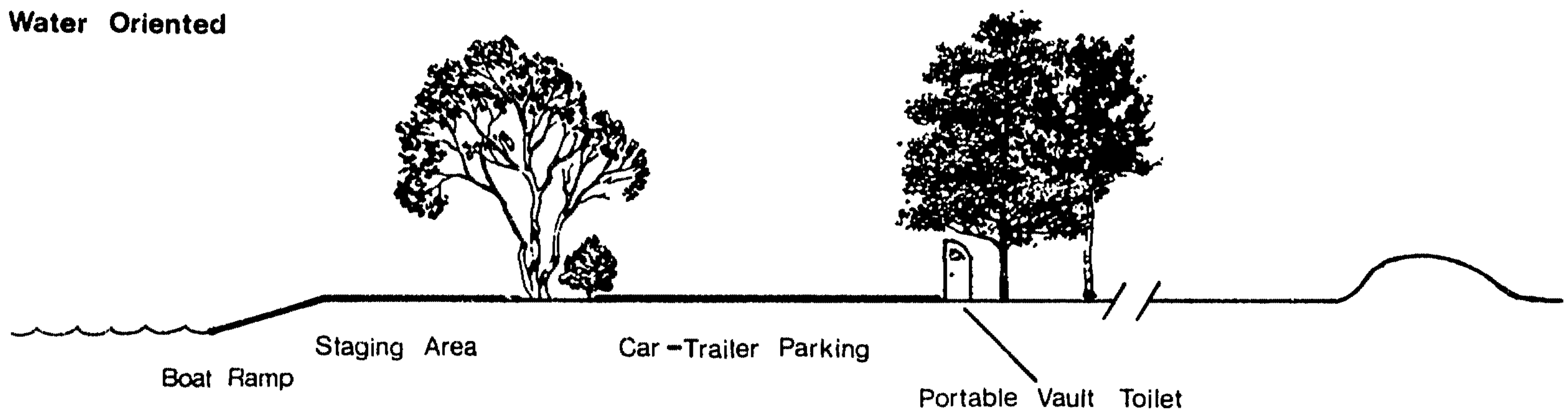


Figure 2

Moveable Structures – in Floodplain

Picnic Area

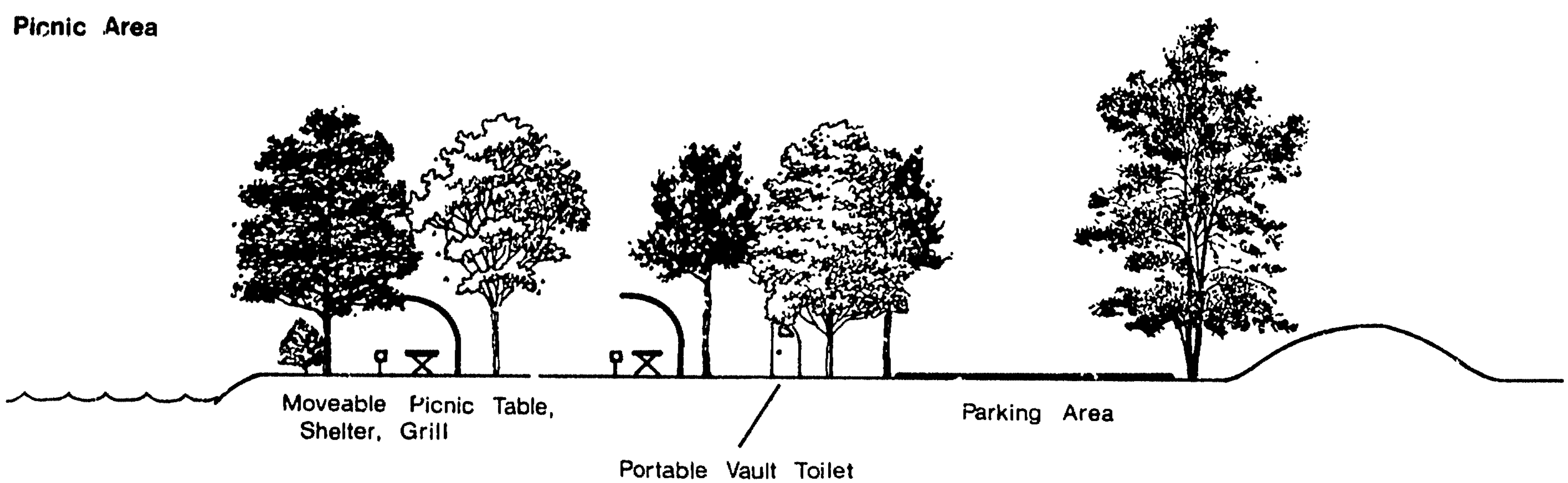


Figure 3

Permanent Structures – Out of Floodplain

Trail

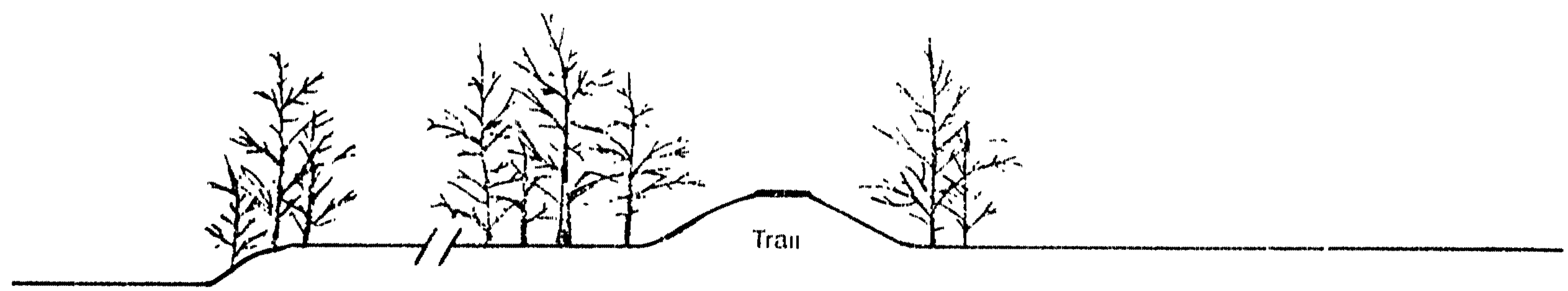
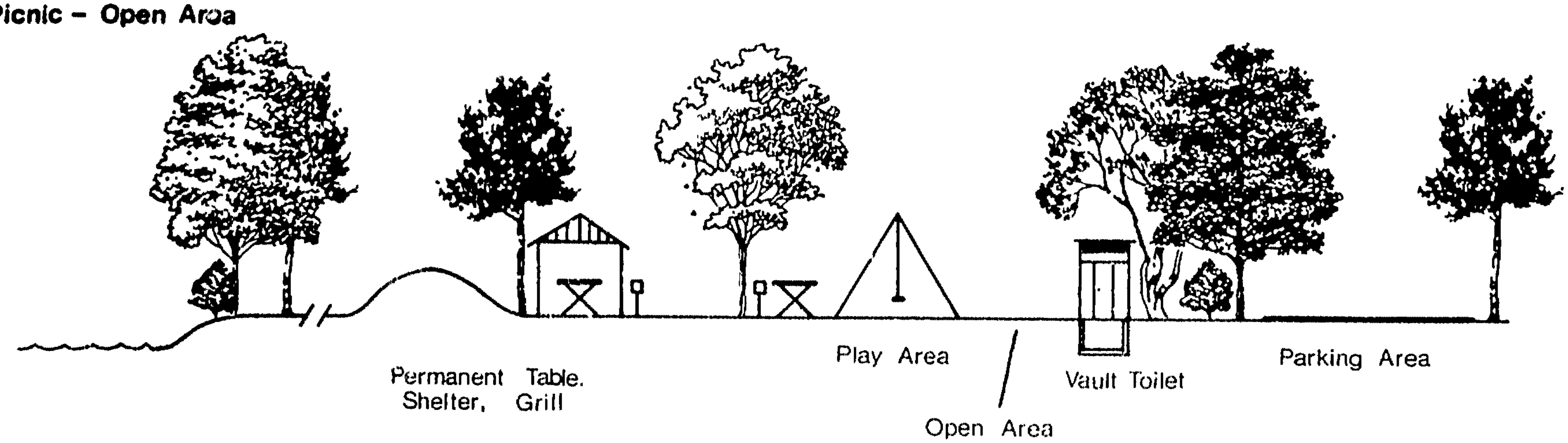


Figure 4

Permanent Structures – Out of Floodplain

Picnic – Open Area



6. Location of Facilities to Minimize Erosion and Sedimentation Problems.

Figure 5 illustrates a typical meander on a river like the Red River of the North. The course of the river typically is composed of a series of tight meander loops. At each end, the channel is shallowest on the inside of the bend, (section 1 point A) and deepest on the outside of the loop (point B). Similarly, erosion is greatest at point B and deposition greatest at point A. Between the bends (section 2), the channel is more uniform. During flood both banks are susceptible to erosion, but point D tends to experience more erosion point C. In addition to the natural tendency for the river channel to migrate from point A to B, the entire loop tends to migrate downstream. That is, the right bank[1] experiences net erosion; the left bank net deposition (in this example). These basic principals are very important to location of recreation areas on a free flowing meandering river cut into soft sediment.

Thus, to avoid problems generated by erosion, the optimum locations are A and C. (All locations are susceptible to problems generated by deposition.) Thus, boat ramps should be located as close as possible to point C. If located at point A, shoaling may make the ramp unuseable during periods of low water. By the same token, facilities located at B and D will experience erosion problems over many years. Trails can be located on either bank, but the set back on the right bank must be greater than on the left bank. Campgrounds, picnic areas and play areas are best located on the left bank. Erosion is less, although sediment deposition will occur during floods.

To summerize, the follow general morphological principles apply to a river like the Red River of the North:

1. Deposition will occur on both banks, but will be greatest on the inside of a meander loop (Point A).

2. Erosion during flood will occur on both banks, but will be greatest on the left bank (Point B) and to a lesser extent in D).

3. The inside of a meander loop tends to have a shallow bar, that, during low water, restricts boat access.

Location of facilities should generally be as follows:

1. Boat ramps: avoid both sides of the bend in the meander loop. Opt for the straight reach between bends. Favor the left bank over the right bank when the straight reach follows a bend to the left as in Figure 5. When the straight reach is preceeded by a bend to the right, favor the right bank.

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[1] To determine the right and left bank, face downstream. The right bank is on the right, the left bank is on the left.

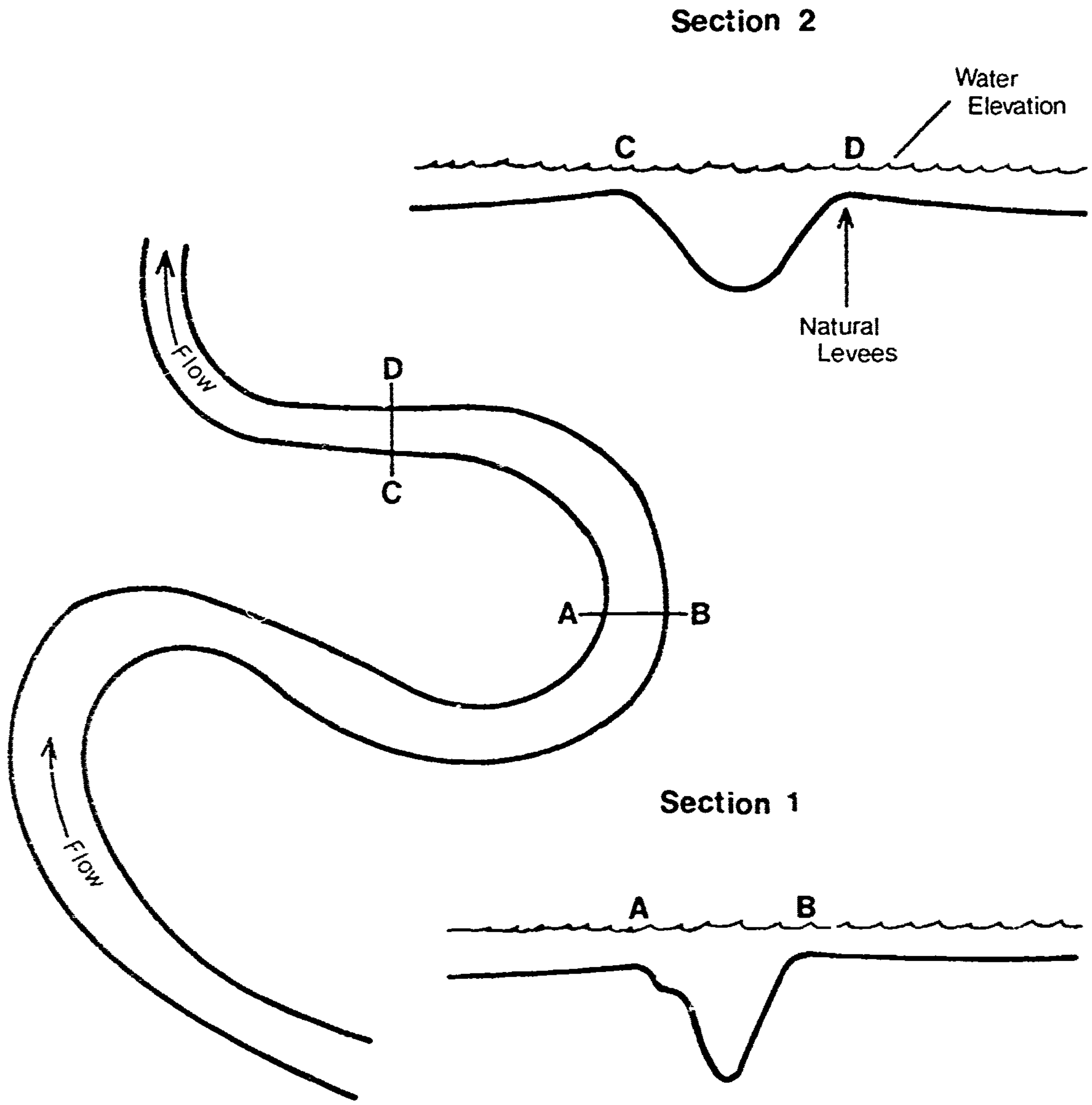

Section 2
Water
Elevation
C
D
Natural
Levees
Flow
D
C
A
B
Flow
Section 1
A
B

Figure 5

2. Campgrounds and picnic areas: avoid the right bank (in a situation similar to Figure 5.) unless there is sufficient room for adequate set back. Adequate set back can be computed if the annual rate of erosion is known. Opt for the left bank wherever possible. The inside of the meander bend is optimum, although deposition will be a problem.

3. Trails: locate on either bank, but the set back must be greater on the right bank than on the left bank. if the situation is similar to that of Figure 5. (The set back must be greater on the left bank for river bends turning right.)

IMPACTS OF LEVEES ON RECREATION FACILITIES

Existing Levees

The levees presently associated with the Red River of the North may have an impact on potential recreation facilities. Where levees are located in potential recreation areas an assessment should be made regarding the compatability of levee dimensions and alignment with the planned facilities. For example, boat ramps may not be compatable with levees near the normal shoreline. Conversely, picninc areas and trails maybe enhanced by the levee related contour changes.

Recreation planning near existing levees must consider the demand for activities in the area. Location of existing levees may eliminate the possibility of providing certain facilities at a given location. Alternative recreation facilities must then be considered. Available land and financing may make development appealing, but it is not advisable to provide recreation opportunities where no need exists.

Proposed Levees

Proposed levee alignment may have an impact on existing and potential recreation facilities. Access roads to existing areas may be severed or portions of the actual recreation area obstructed due to levee location. Also, levee alignment close to the normal shoreline may hamper use of existing facilities associated with the river. Fishing accesses or boat ramps may be rendered unusable. The extent of the impact will depend on levee alignment and design.

The aesthetic quality of the river environment may also be affected. River scenery viewed from existing roads or walkways may be blocked due to levee placement. Also, a levee constructed near the normal shoreline will alter the visual quality of the river environment.

Positive impacts can result by incorporating levees into recreation planning. Contour changes provided by levees can enhance a recreation area by adding dimension and variety in topography. Visual and audible characteristics of certain activities can be minimized by effective levee placement--making a wider variety of activities possible in a given area. Consideration must be given to floodproofing facililties located on the river side of the levee.

Potential recreation facilities may also be affected by proposed levee alignment. The concerns discussed in the preceeding paragraphs apply. but here both recreation facilities and levee structures are in the planning stages. Impact to recreation areas can be minimized, if not eliminated, by integrating recreation plans with levee design and alignment.

SITE-SPECIFIC POTENTIAL IMPACTS

Existing and potential recreation facilities have been assessed regarding possible impact due to the four flood control alternatives being considered. This is a tentative assessment in that exact locations of proposed levee alignments and possible recreation areas have not yet been determined.

The following paragraphs briefly discuss potential site-specific impacts of levee additions. The criteria used to determine which areas may be impacted is proximity of existing and proposed levee alignments to existing and proposed recreation areas. The planning process is in the conceptual stages. As planning progresses and additional data becomes available potentially impacted sites may incur only slight or no adverse effects due to levee alignment. However, the degree of impact at each site cannot be determined at this time.

Alternative

The equal setback levee concept, where levees would be constructed to match existing levees on opposite banks, may have an impact on Potential Site 8 (see map 13). Levees currently exist on the North Dakota bank across from these sites. Addition of levees on the Minnesota side to follow the curves of existing North Dakota levees may cut across these sites and reduce their recreation potential.

Alternative

Another alternative is to locate levees to meet North Dakota's and Minnesota's 100-year flood protection criteria. If undertaken, this alternative may impact two existing sites: Drayton Municipal Park and Drayton Municipal Golf Course (see map 7). These areas are on an elevated location just above the 100-year floodplain. Site 1,a potential recreation area near the Pembina River may also be impacted(see map 1).

Alternative

The third action alternative--to re-align existing levees where necessary and equalize the length of opposing levees--may have an impact on proposed Sites 7 and 8 (see map 13). Levees added on the Minnesota bank to match existing or renovated alignments on the North Dakota side may cut across the potential recreation areas.

Alternative

The fourth alternative, "No Action", involves no levee construction or modification. Under this situation no additional impacts of existing levees to existing and proposed recreation areas will occur. Present levee alignments are not having an input on existing recreation facilities in the study area.

COST ESTIMATES

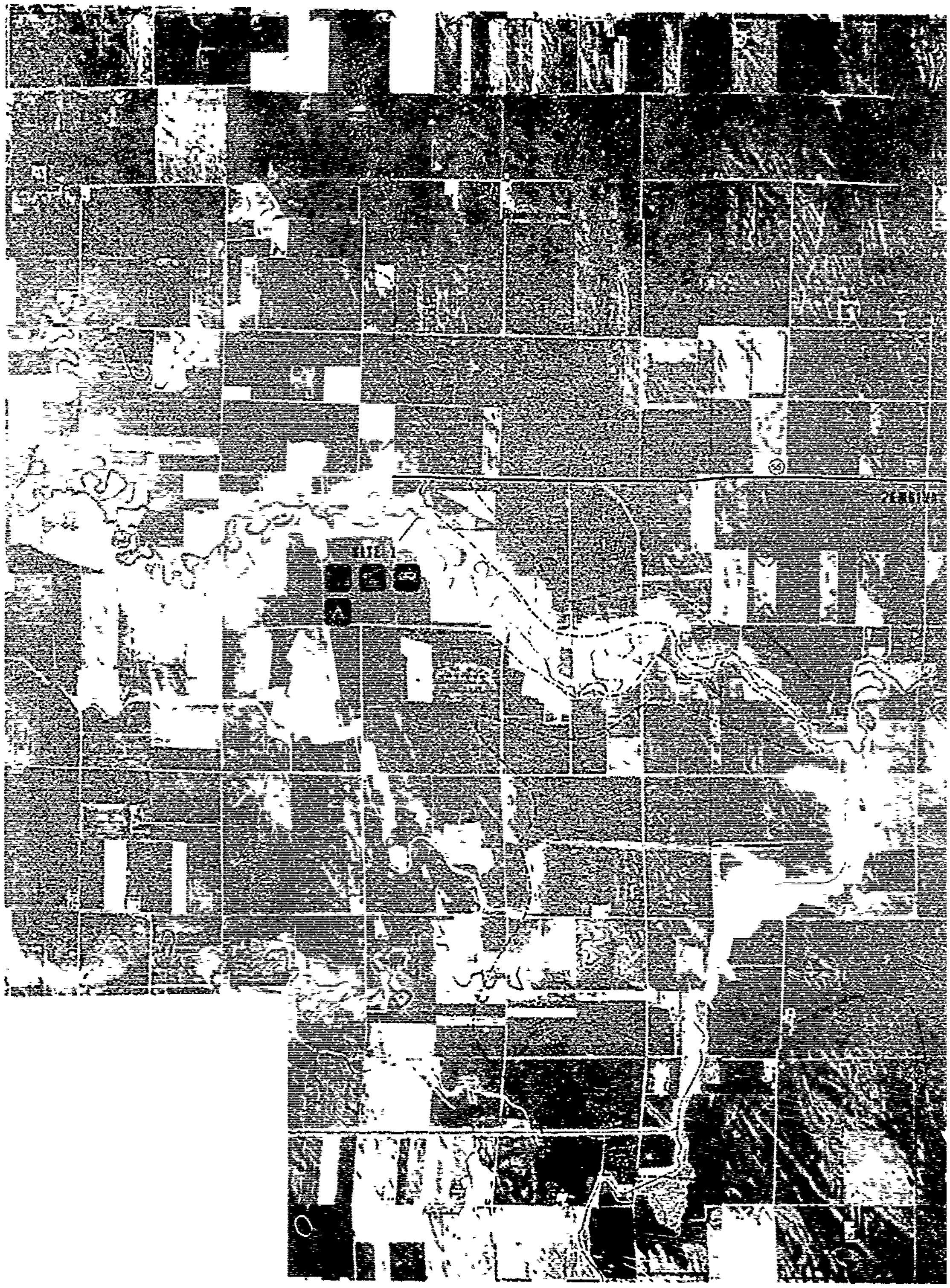
Construction cost estimates for recreation facilities discussed earlier are presented in Table 5. Several factors influence to a large degree the cost of these facilites. These are: transportation distances, local economics, pre-construction site preparation, project scope, facility specifications, and the local construction market. Fluctuation in any of these areas can cause cost estimates to not be a true indication of actual costs. The purpose of providing these estimates is to give some idea as to approximate costs. The prices in Table 5 must be interpreted as guidelines only. Actual costs, or even preliminary cost estimates, must be calculated where pricing factors can be more accurately determined.

It must be made clear that the figures in Table 5 do not include costs associated with consultants, test borirgs, permits, administration or contingencies. Price estimates were provided by two public agencies who provide recreation facilites. Park planning guideline manuals were also consulted. Prices not in cuurent dollars were adjusted by using a construction cost index and therefore may not have accounted for unforeseen charges in the general economy and constuction industry.

TABLE 5
RECREATION FACILITY COST ESTIMATES

Item	Cost ($)
Parking Lot (Bituminous)	13-29 yd^2
Access Road (10′-12′)	40 lft
Bicycle Path (paved, with shoulder & grading)	6-12 lft
Boat Ramp*	11,500 ea.
Cross Country Trail	"minimal"
Snowmobile Trail	"minimal"
Hiking Trail (wood chip)	N/A
Campsite (developed)	2200-2800 ea.
Horeseshoe Pits*	600 pr.
Picnic Shelter(w/cement base)*	33,800 ea.
Play Structure (full-scale wood)	16,000-83,000 ea.
Picnic Table*	150 ea.
Cooking Grate*	85 ea.
Trash Receptacle	2-67 ea.
Water Fountain (full, handicapped)	1800 ea.
Bath House	58,000-94,000 ea.
Vault Toilet*	5000 pr.
Flush Toilet (mens & womens)*	41,000 ea.
Beach Sand*	6 yd^3
Water Line (1-1/2")	4-16 lft
Sewer Line (8")	11-17 lft
Electrical Line (underground)	10-13 lft

* based on one estimate N/A estimate not available



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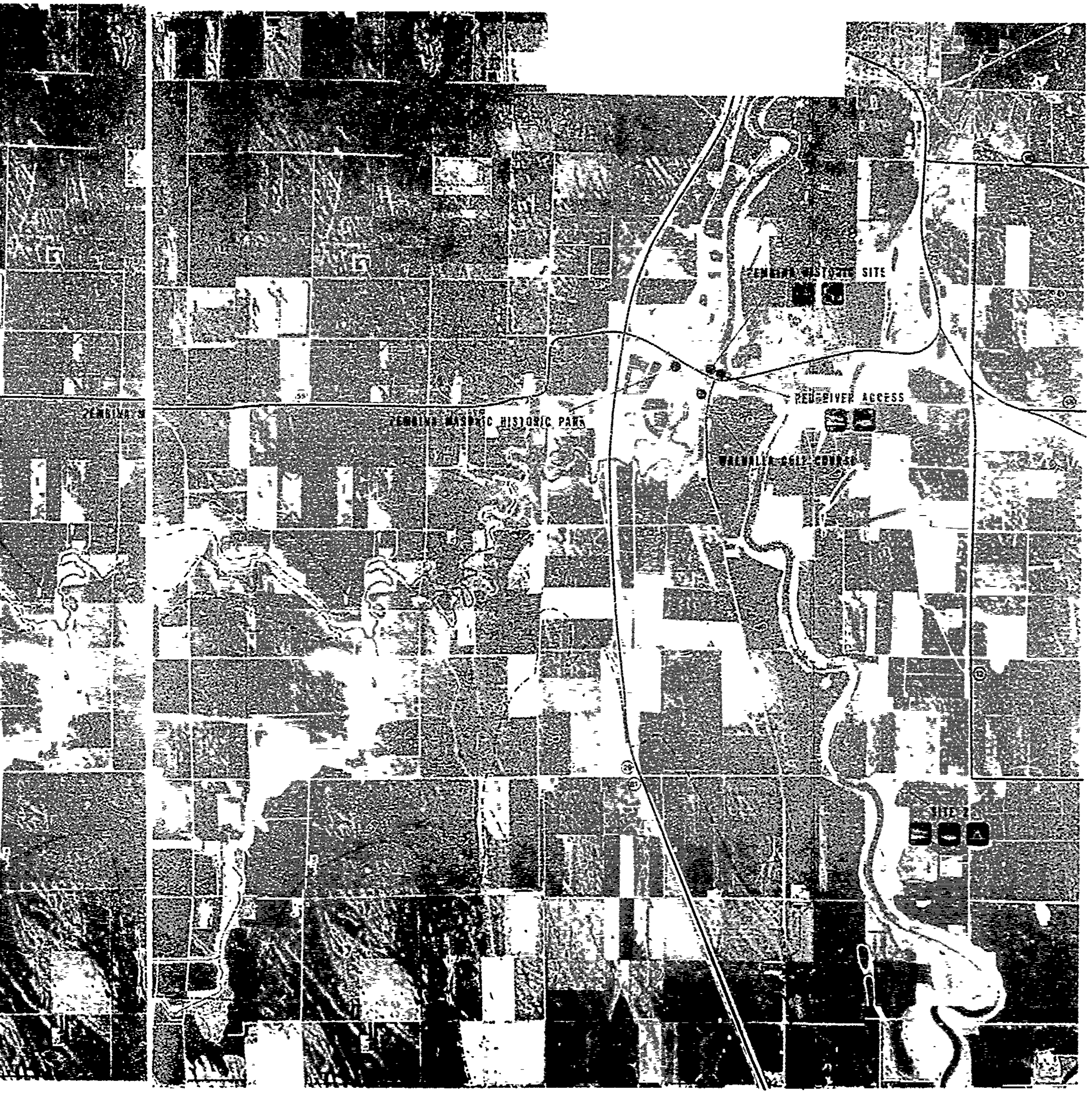

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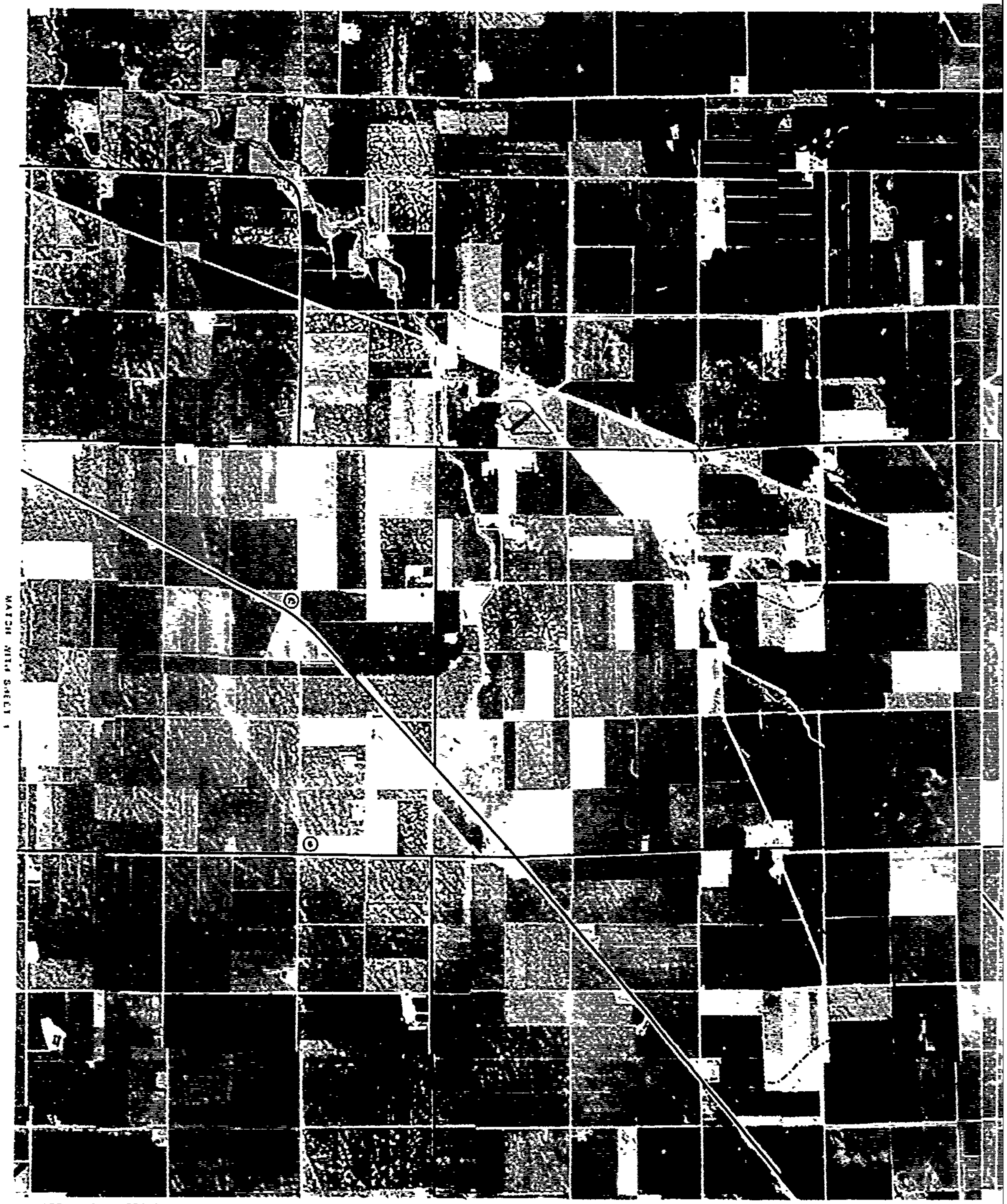
RED RIVER VALLEY



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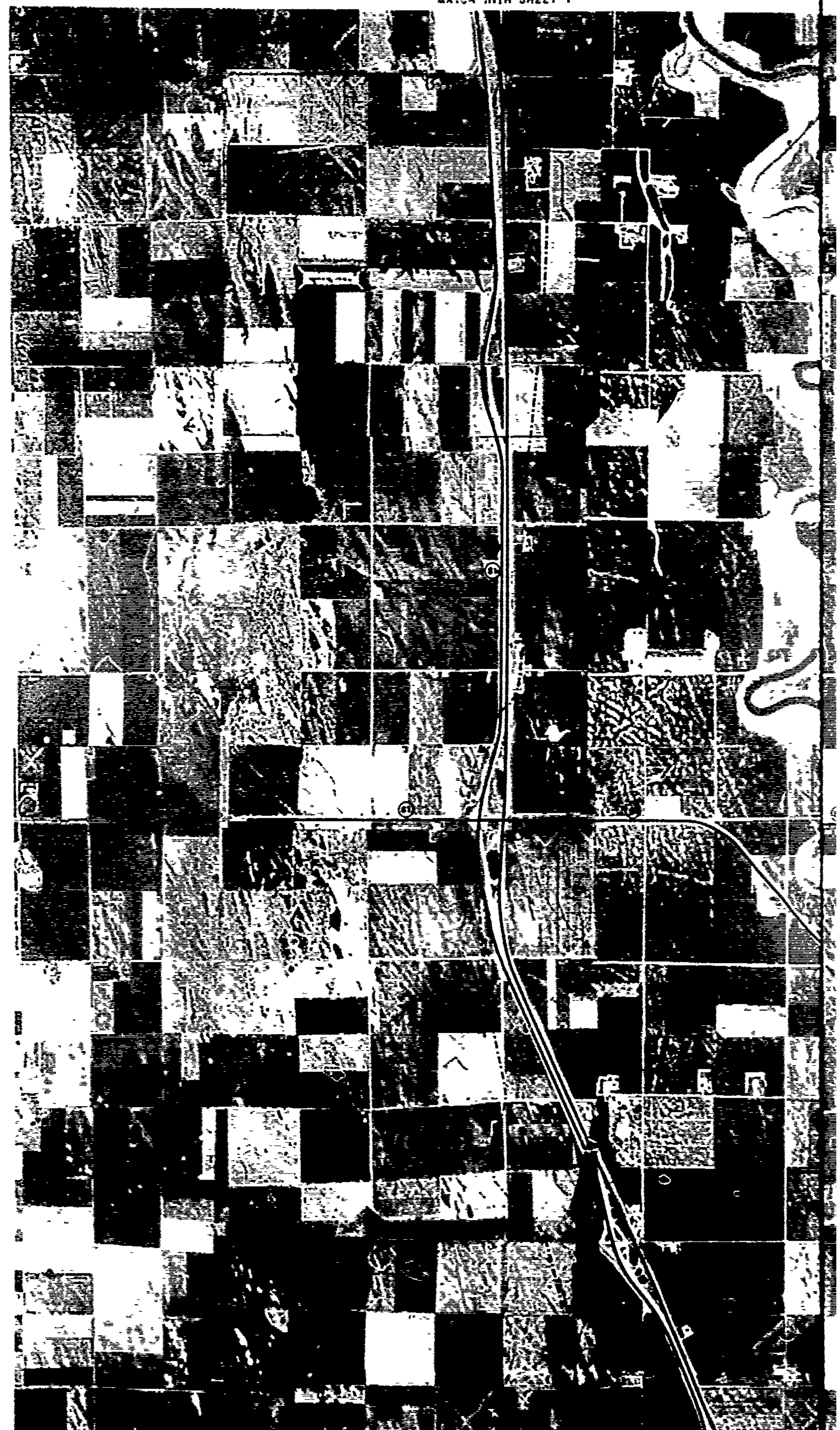

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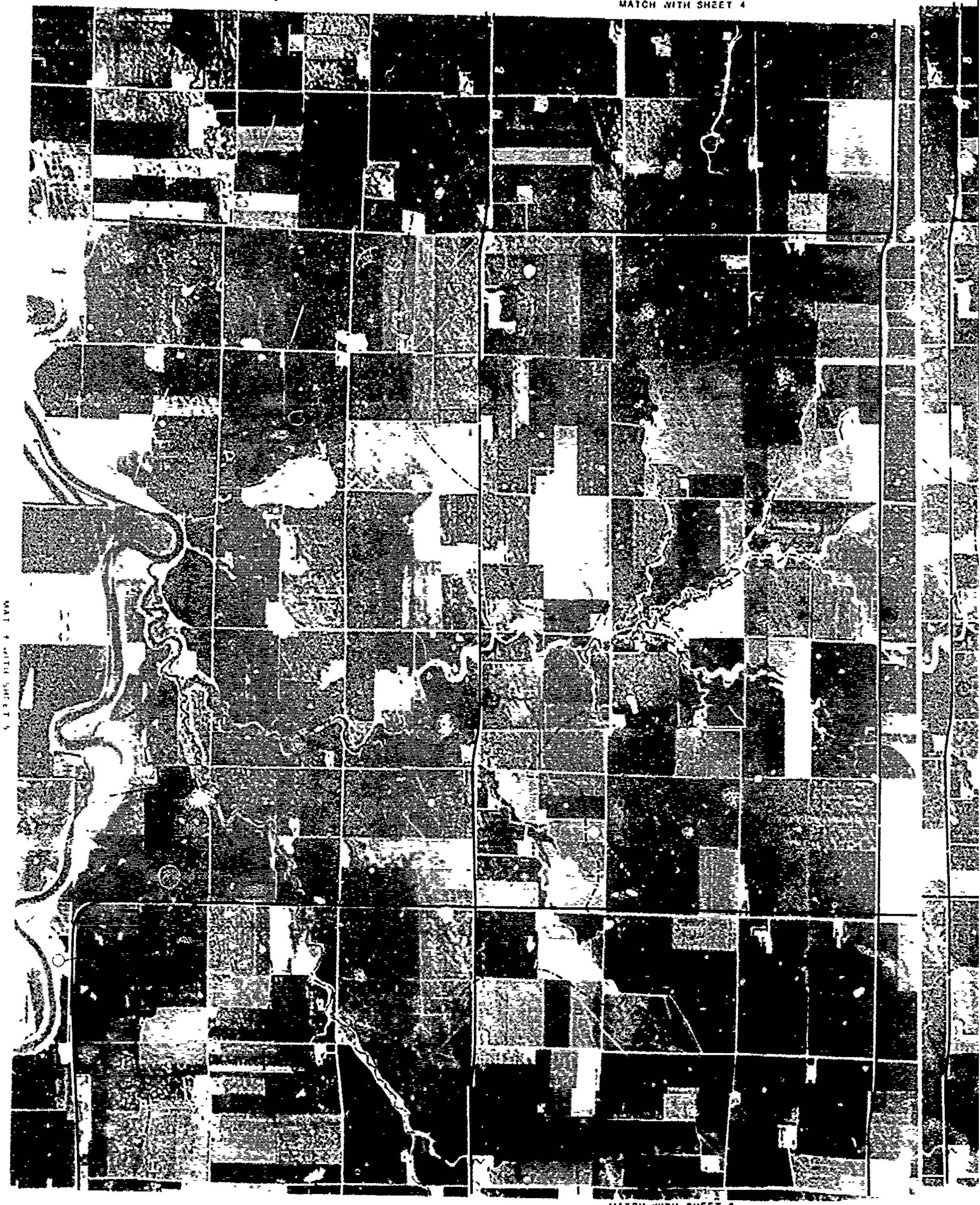

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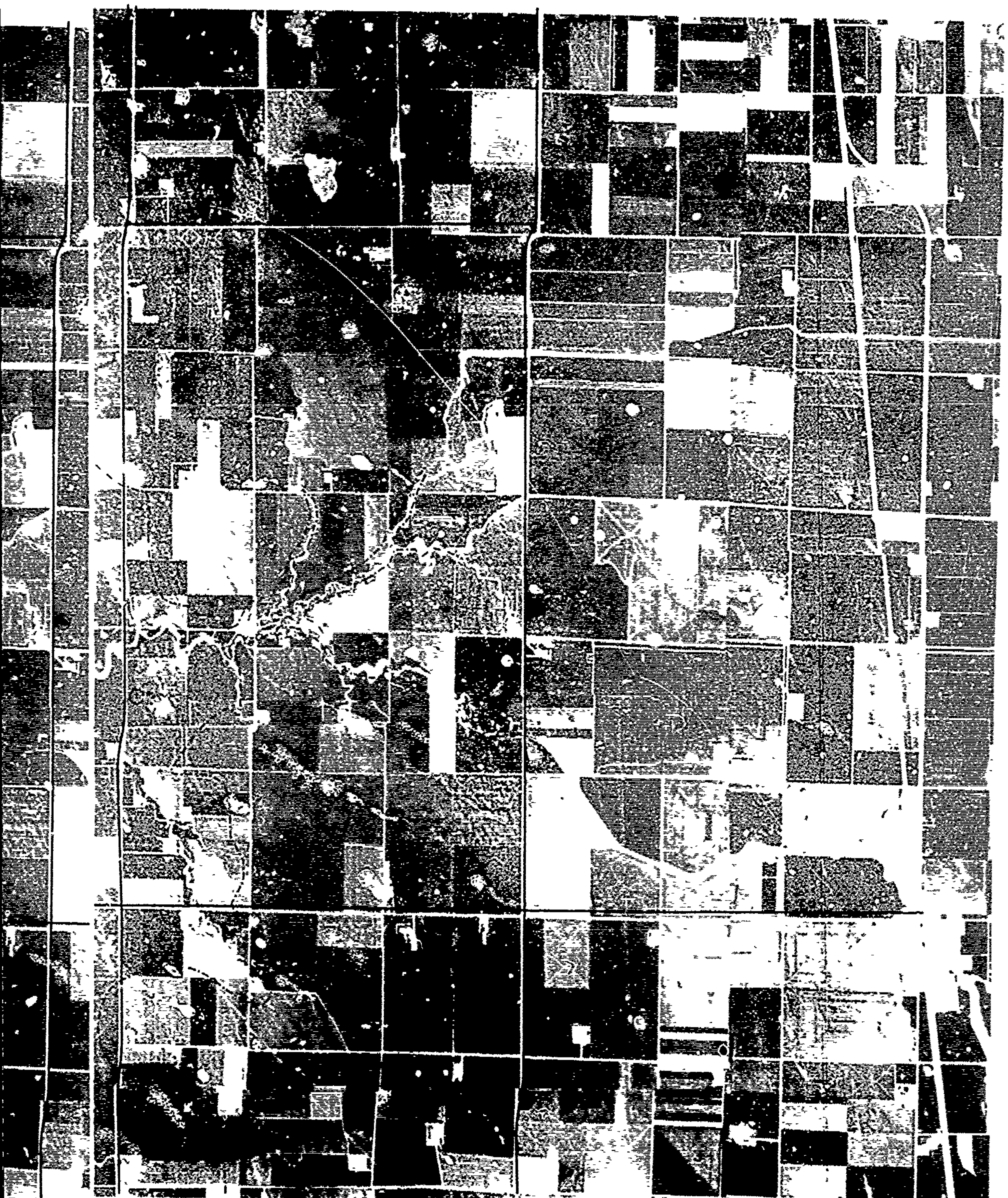

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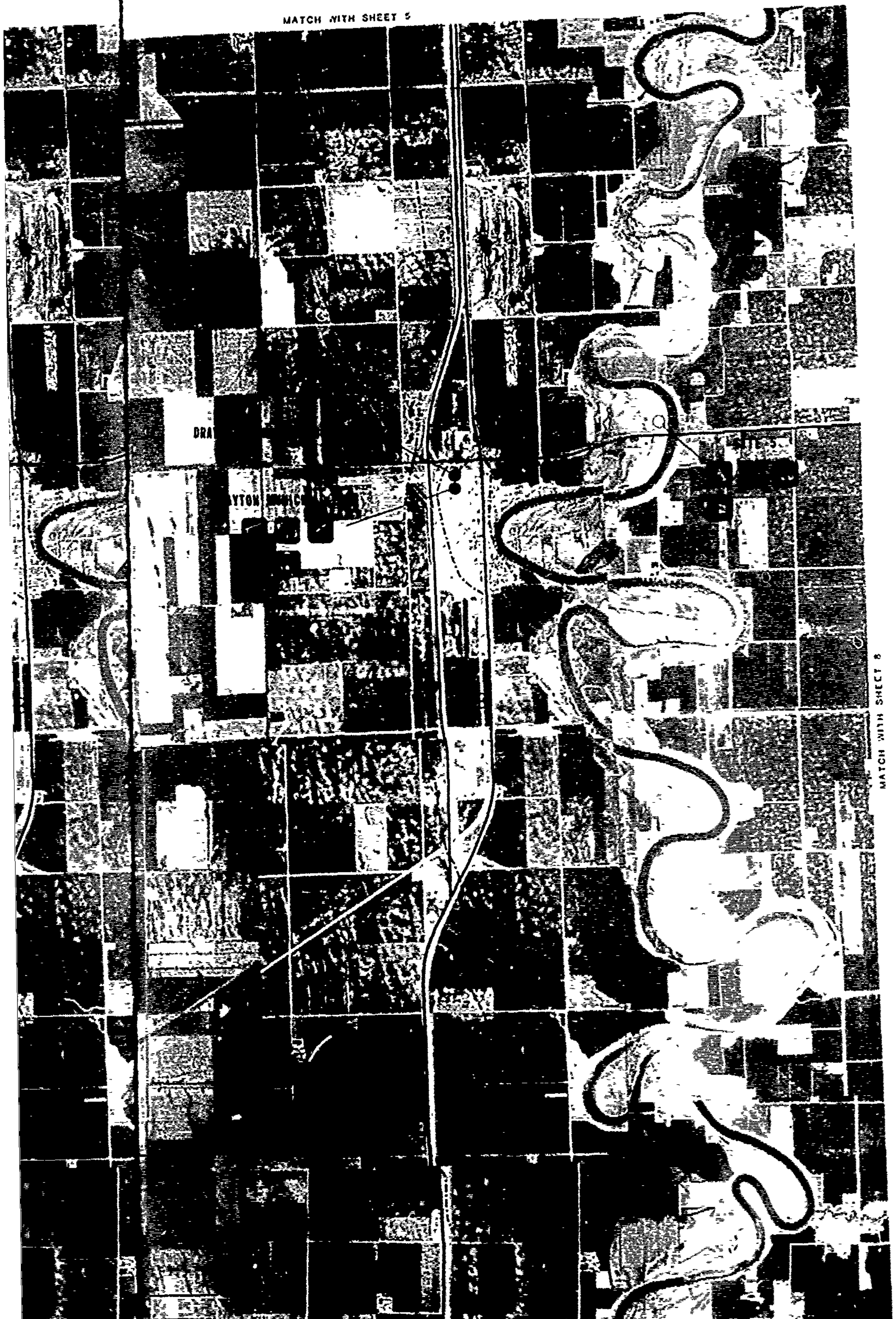

LEGEND

- EXISTING REC AREAS
- POTENTIAL REC. AREAS
- MAJOR HIGHWAYS
- REGIONAL FLOODPLAIN AREA
- EXISTING LEVEES (MAY 1981)

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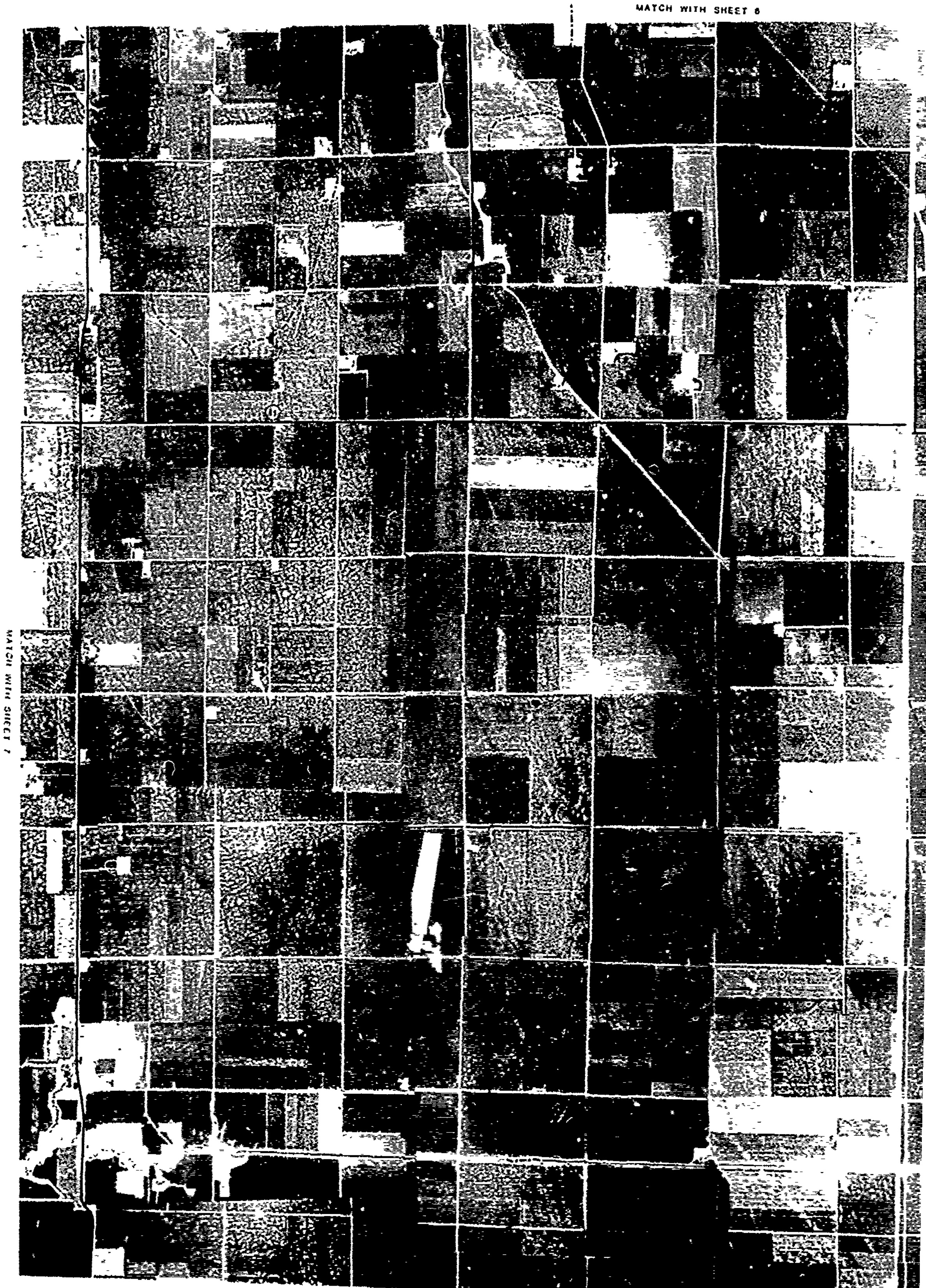

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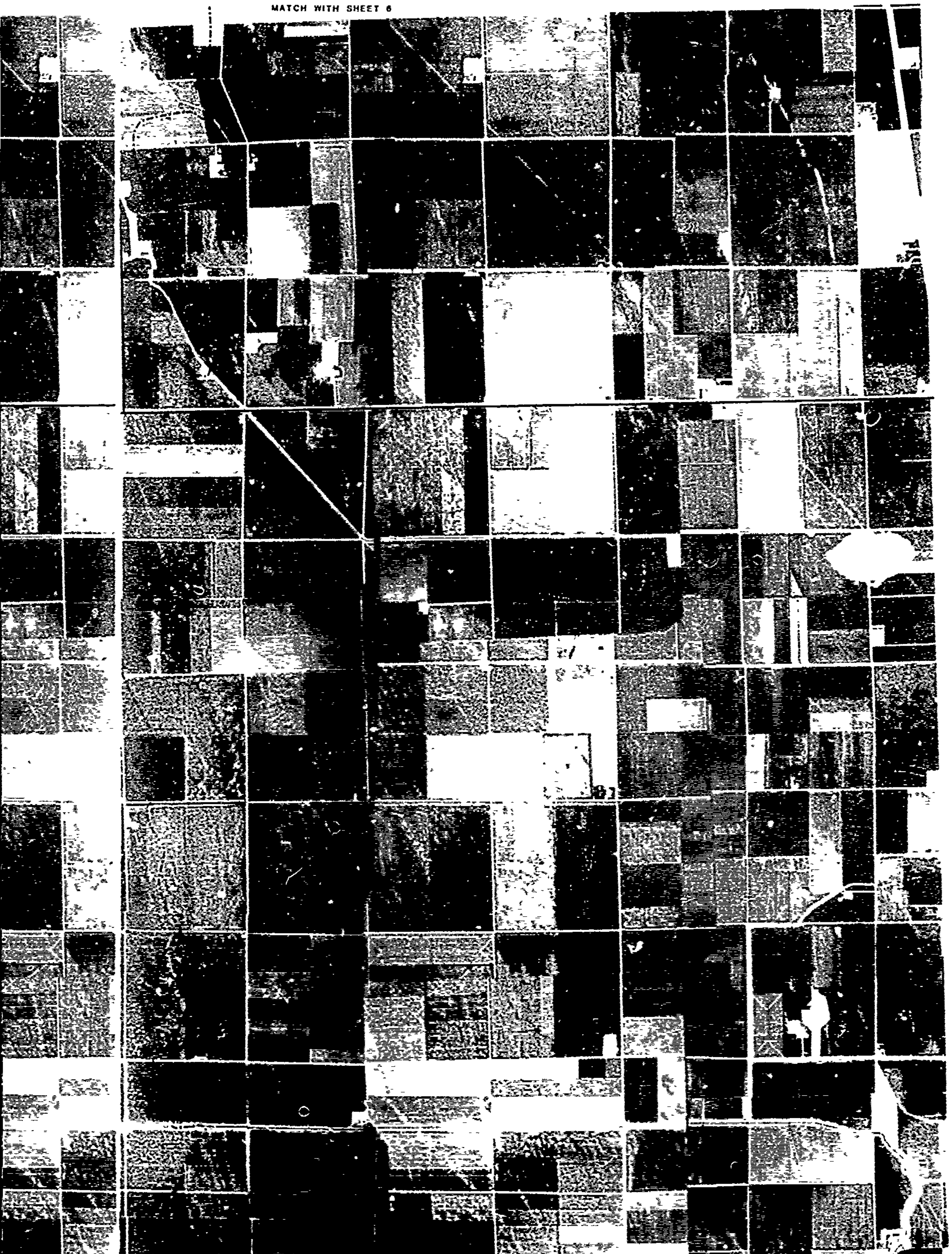

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MATCH WITH SHEET 11

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SCALE IN MILES

1 : 24,000

CORPS OF ENGINEERS, U.S. ARMY

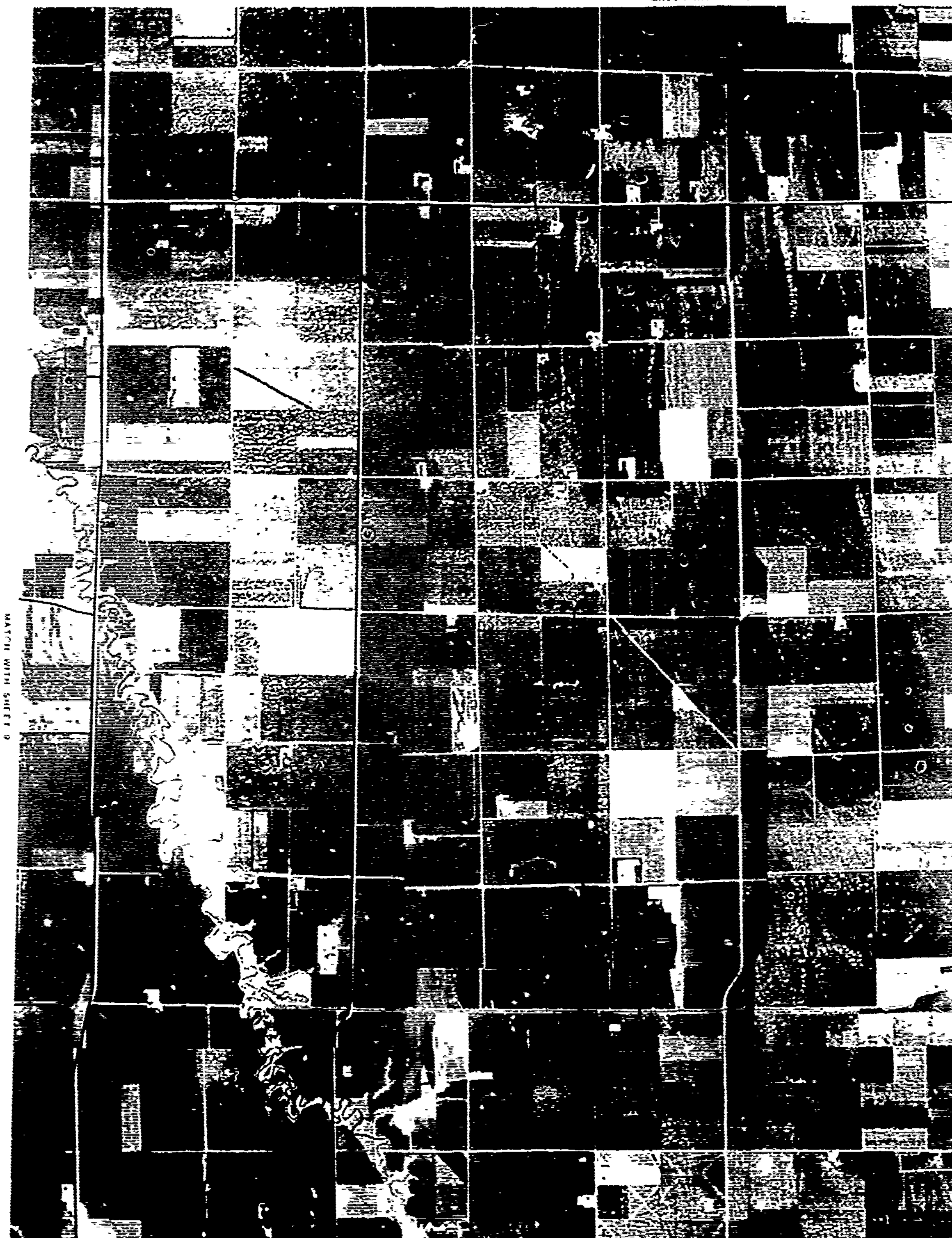
ST. PAUL DISTRICT - ST. PAUL, MINNESOTA

RED RIVER VALLEY

SHT. 9 OF 16

MATCH WITH SHEET 8

MATCH WITH SHEET 9



MATCH WITH SHEET 12

WESTON

PHOTOGRAPHY COMPLETED : JULY 16, 1979

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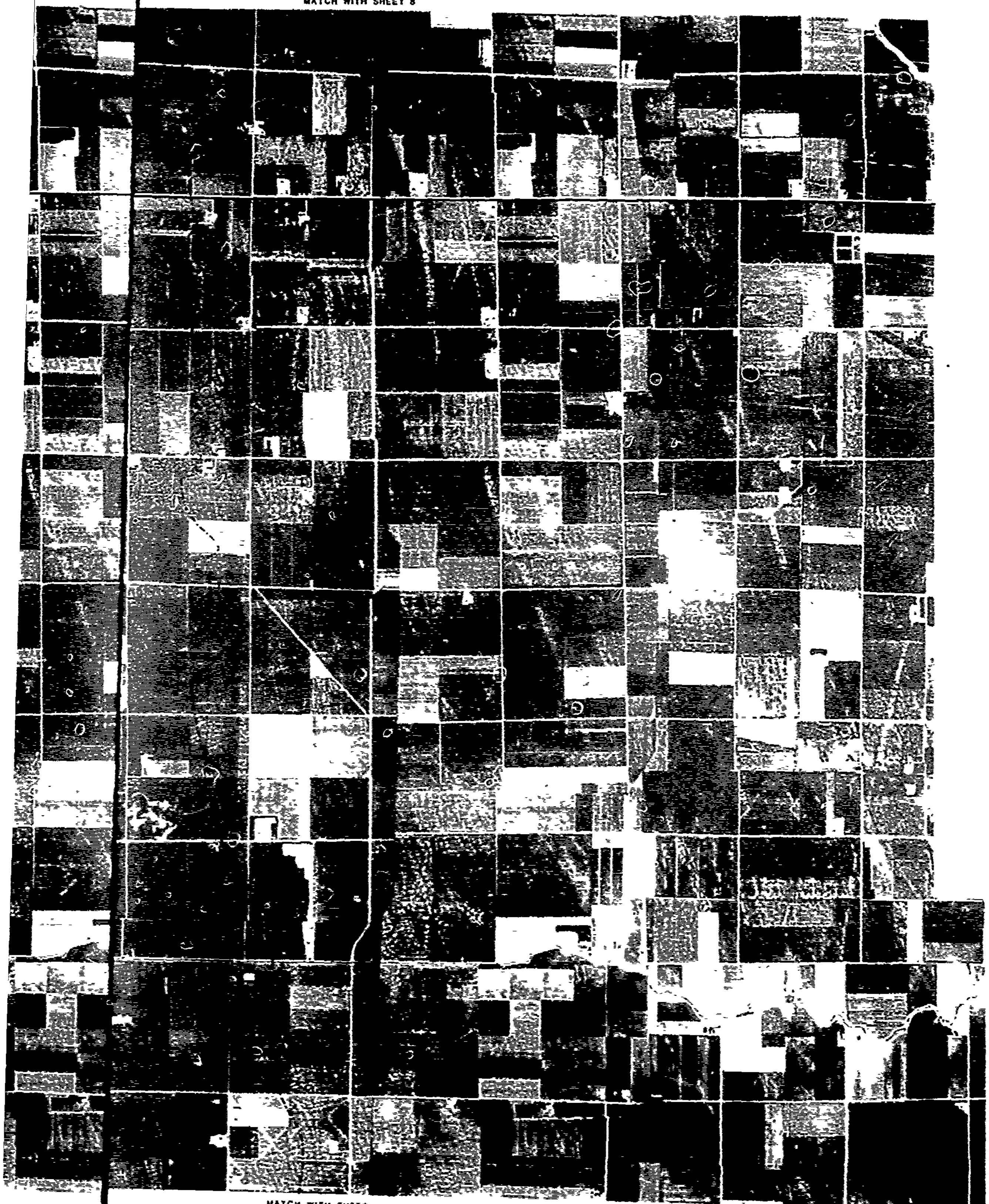

MATCH WITH SHEET 12

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SCALE IN MILES

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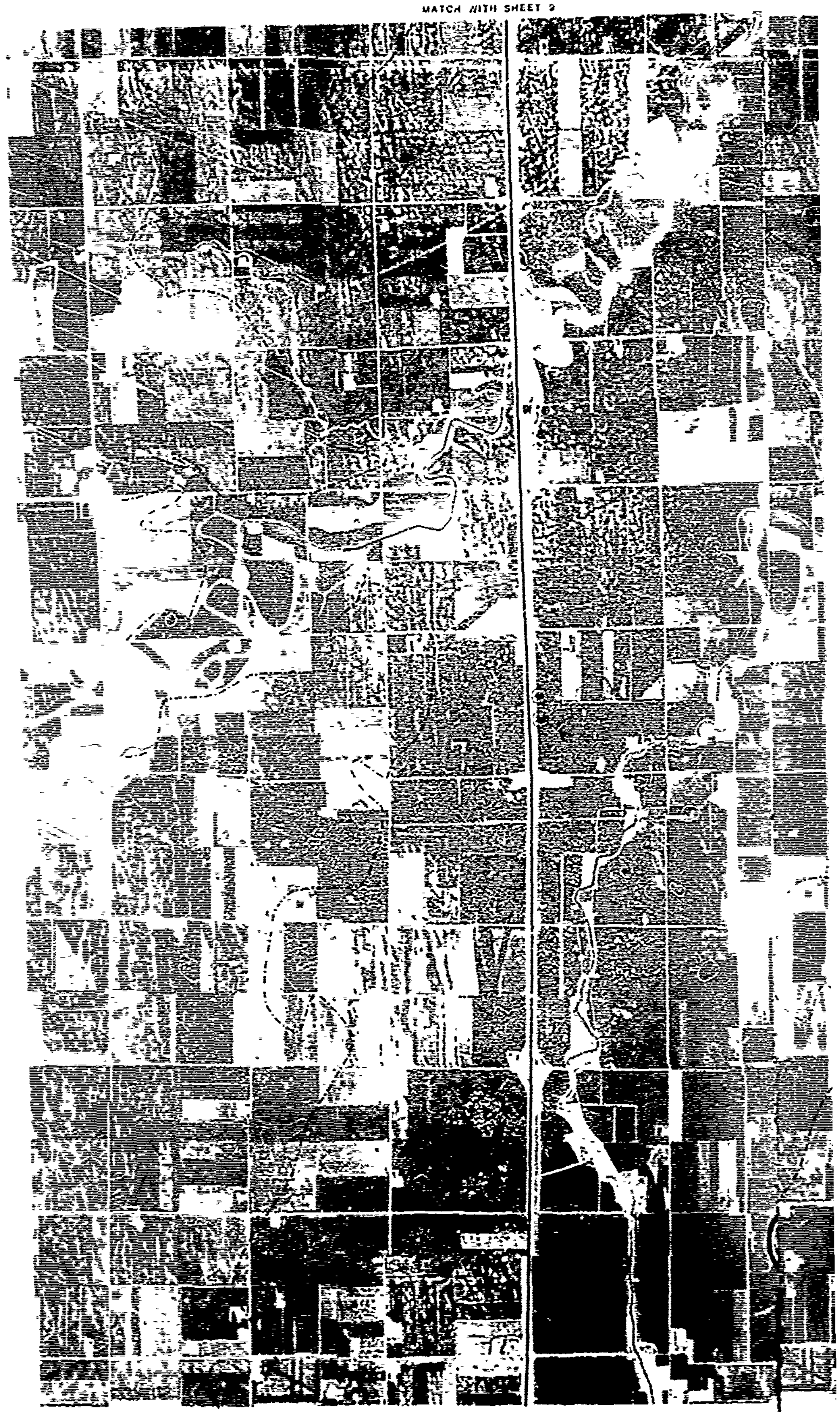
CORPS OF ENGINEERS, U.S. ARMY
ST. PAUL DISTRICT - ST. PAUL, MINNESOTA
RED RIVER VALLEY
SHT. 10 OF 16

MATCH WITH SHEET 9



MATCH WITH SHEET 13

WESTON

PHOTOGRAPHY COMPLETED : JULY 16, 1979

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SCALE IN MILES

N

SCALE

MATCH WITH SHEET 9

MATCH WITH SHEET 13

0 1 2

SCALE IN MILES

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1 : 24,000

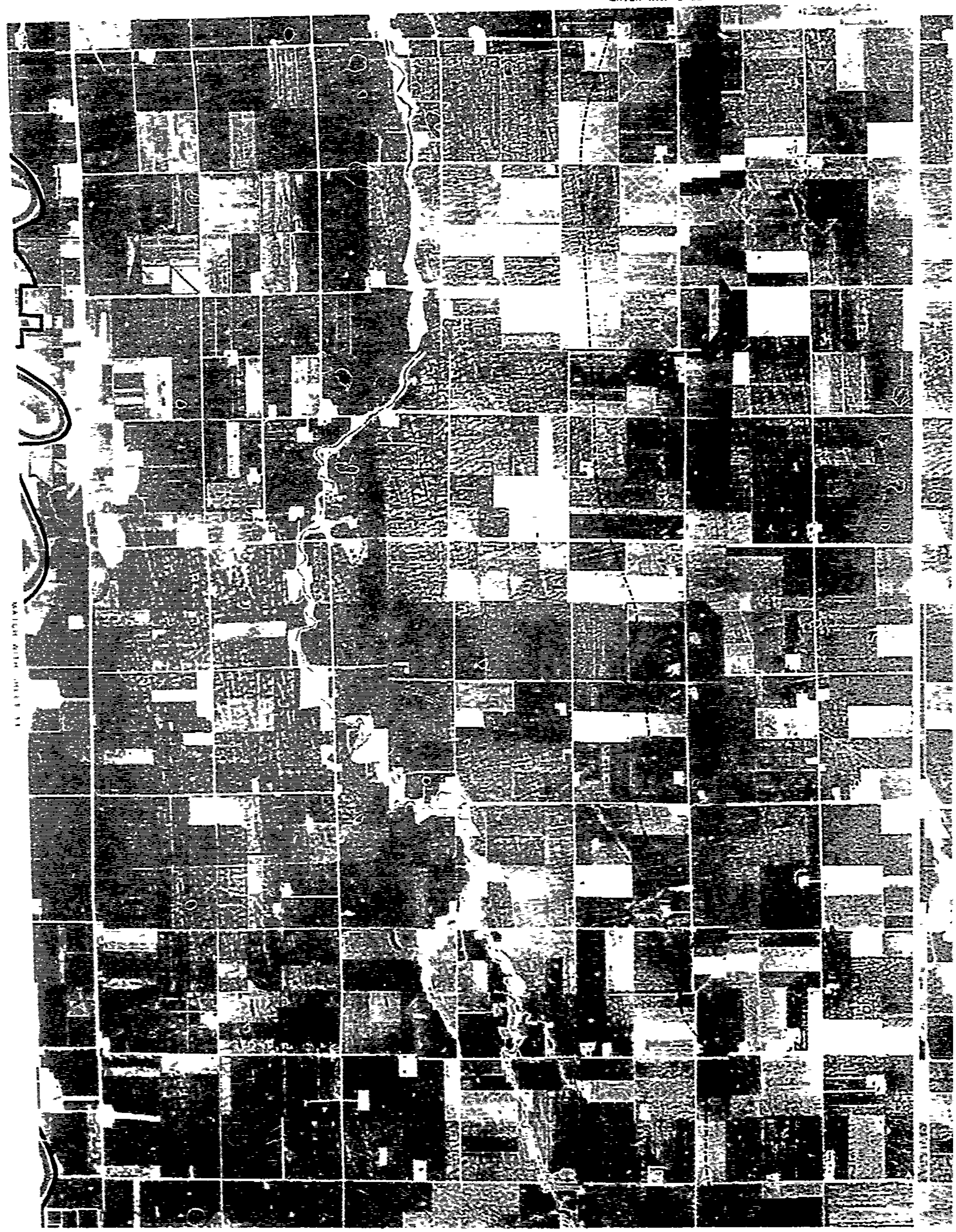
CORPS OF ENGINEERS, U.S. ARMY

ST. PAUL DISTRICT - ST. PAUL, MINNESOTA

RED RIVER VALLEY

SHT. 11 OF 16

MATCH WITH SHEET 10



MATCH WITH SHEET 14

WESTON

PHOTOGRAPHY COMPLETED : JULY 16, 1979

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SCALE IN MILES

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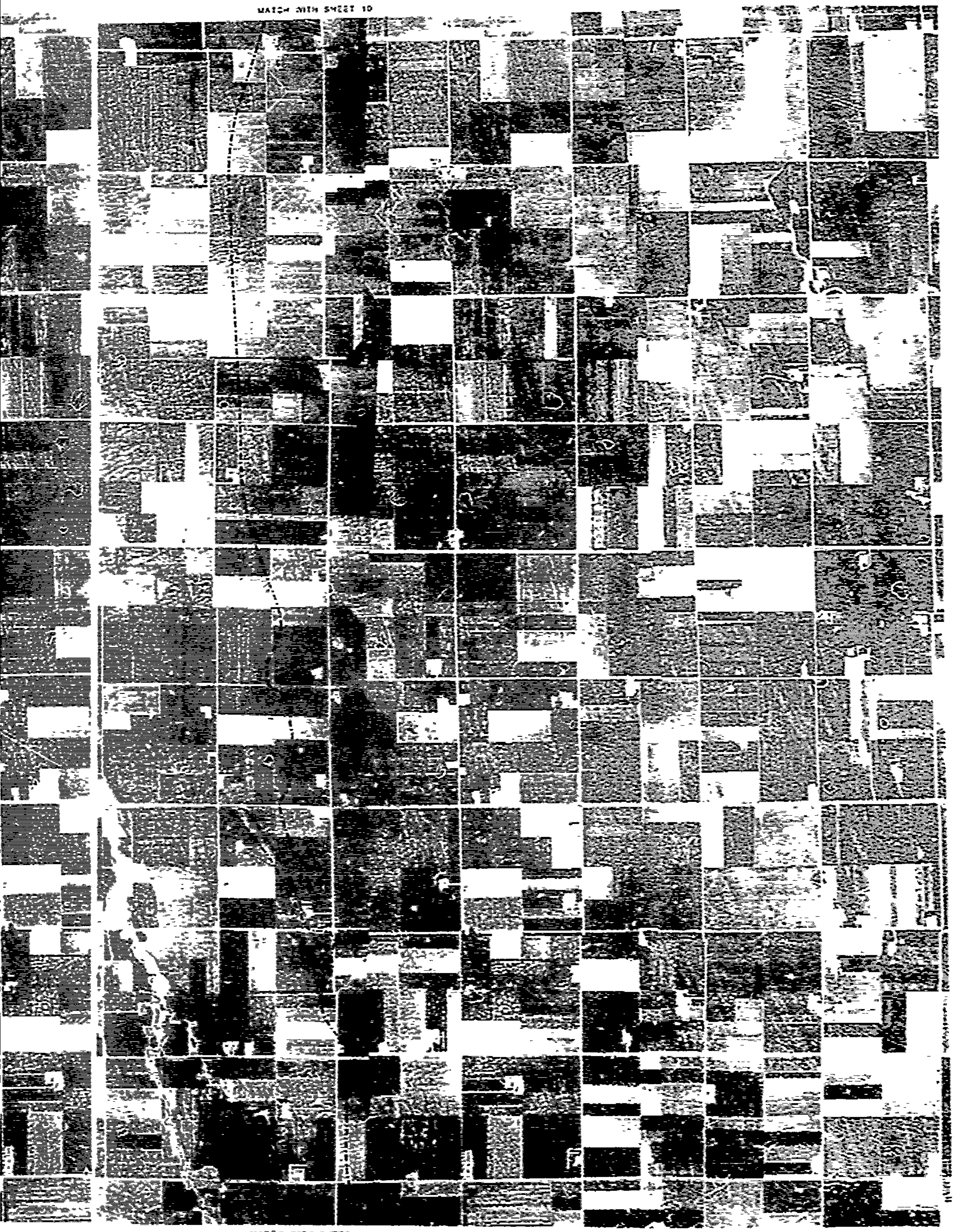


MATCH WITH SHEET 14

0 1 2

SCALE IN MILES

1 : 24,000

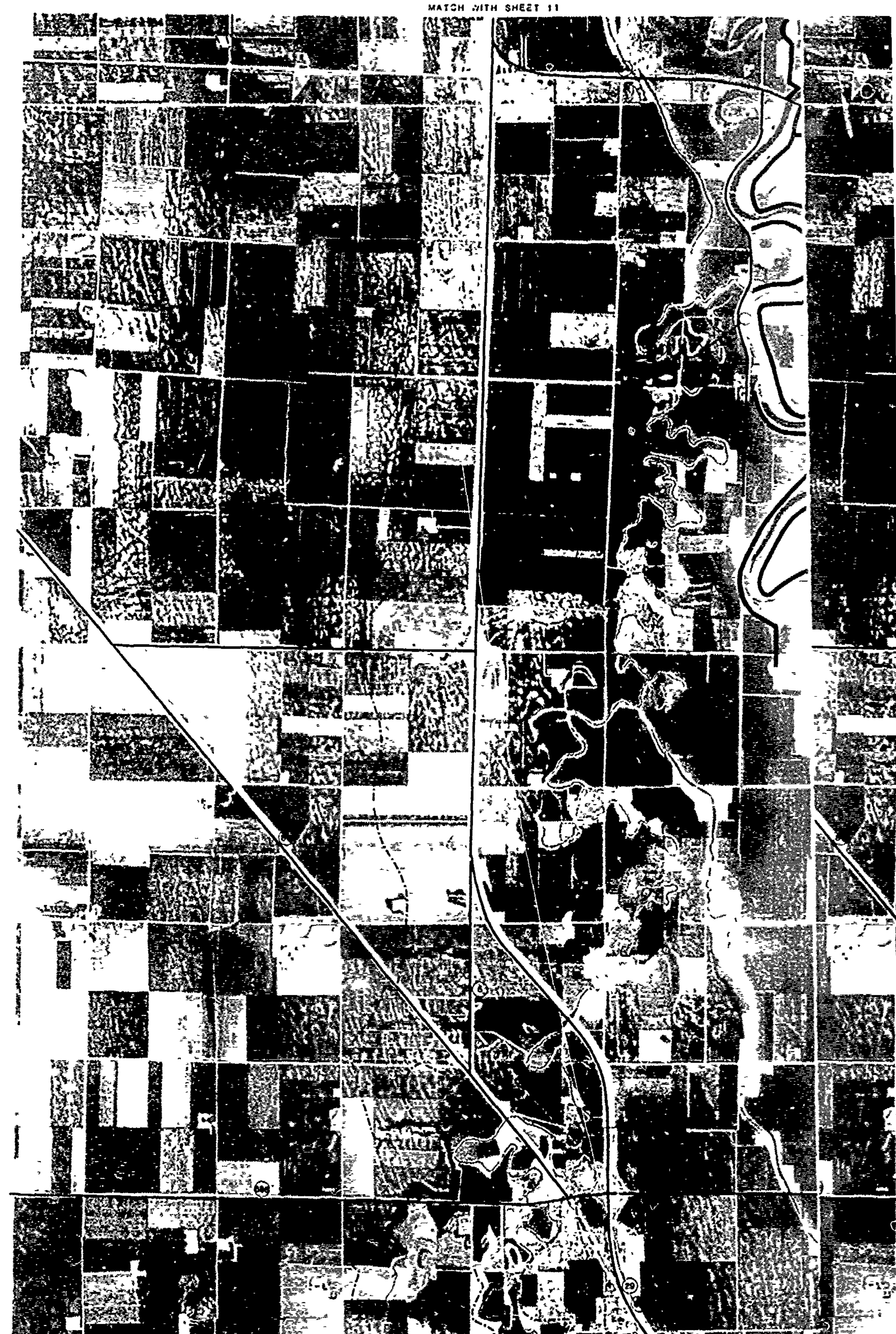
CORPS OF ENGINEERS, U.S. ARMY

ST. PAUL DISTRICT - ST. PAUL, MINNESOTA

RED RIVER VALLEY

SHT. 12 OF 14

MATCH WITH SHEET 11



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WESTON

PHOTOGRAPHY COMPLETED : JULY 16, 1979

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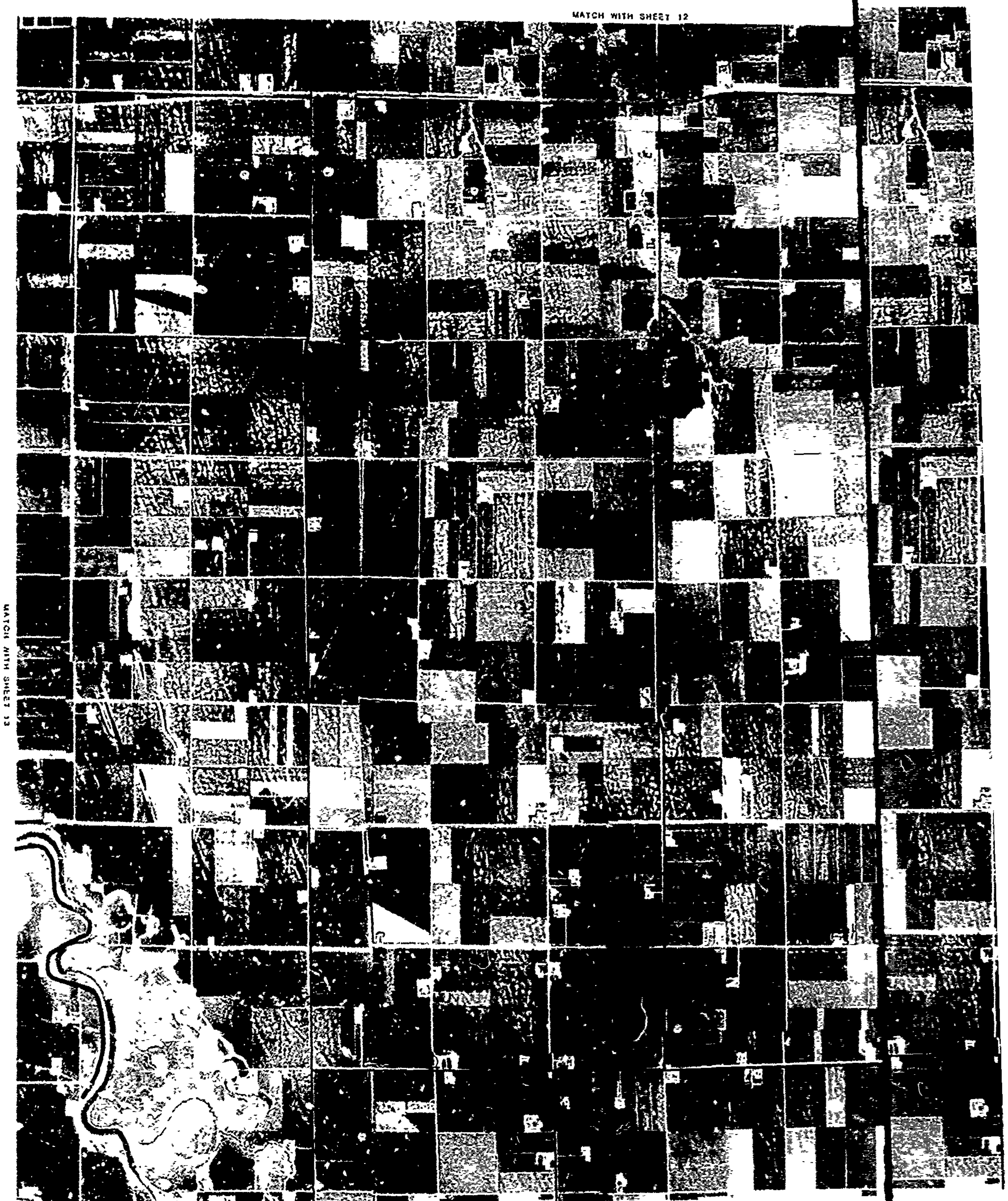
CORPS OF ENGINEERS, U.S. ARMY
ST. PAUL DISTRICT - ST. PAUL, MINNESOTA

RED RIVER VALLEY

13 SHT. OF 16



WESTON

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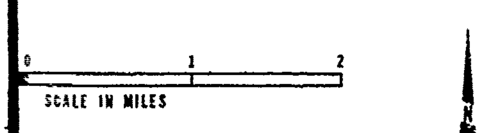
MATCH WITH SHEET 12

MATCH WITH SHEET 16



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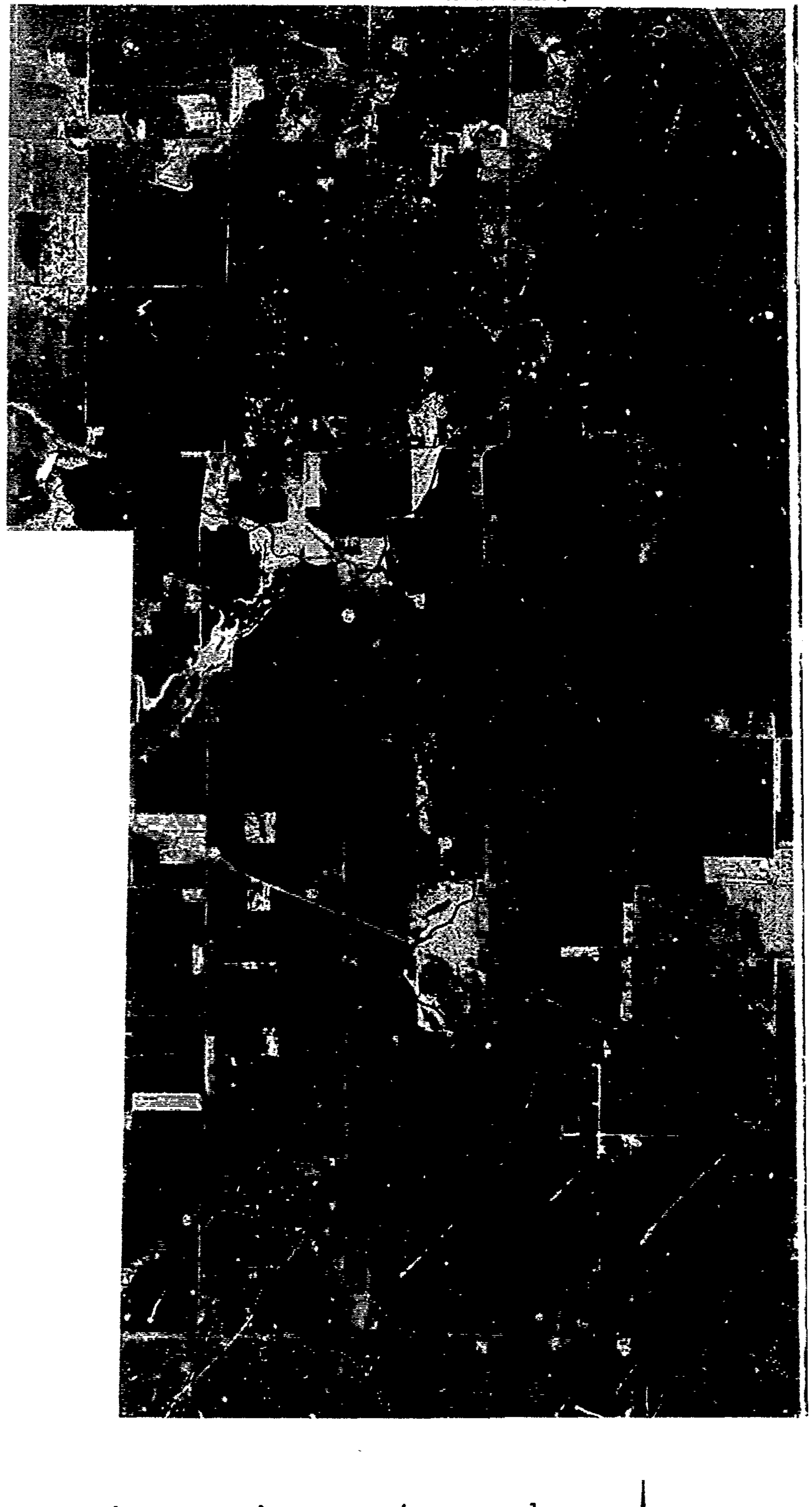
CORPS OF ENGINEERS, U.S. ARMY
ST. PAUL DISTRICT - ST. PAUL, MINNESOTA
RED RIVER VALLEY
SHT 14 OF 16

MATCH WITH SHEET 13



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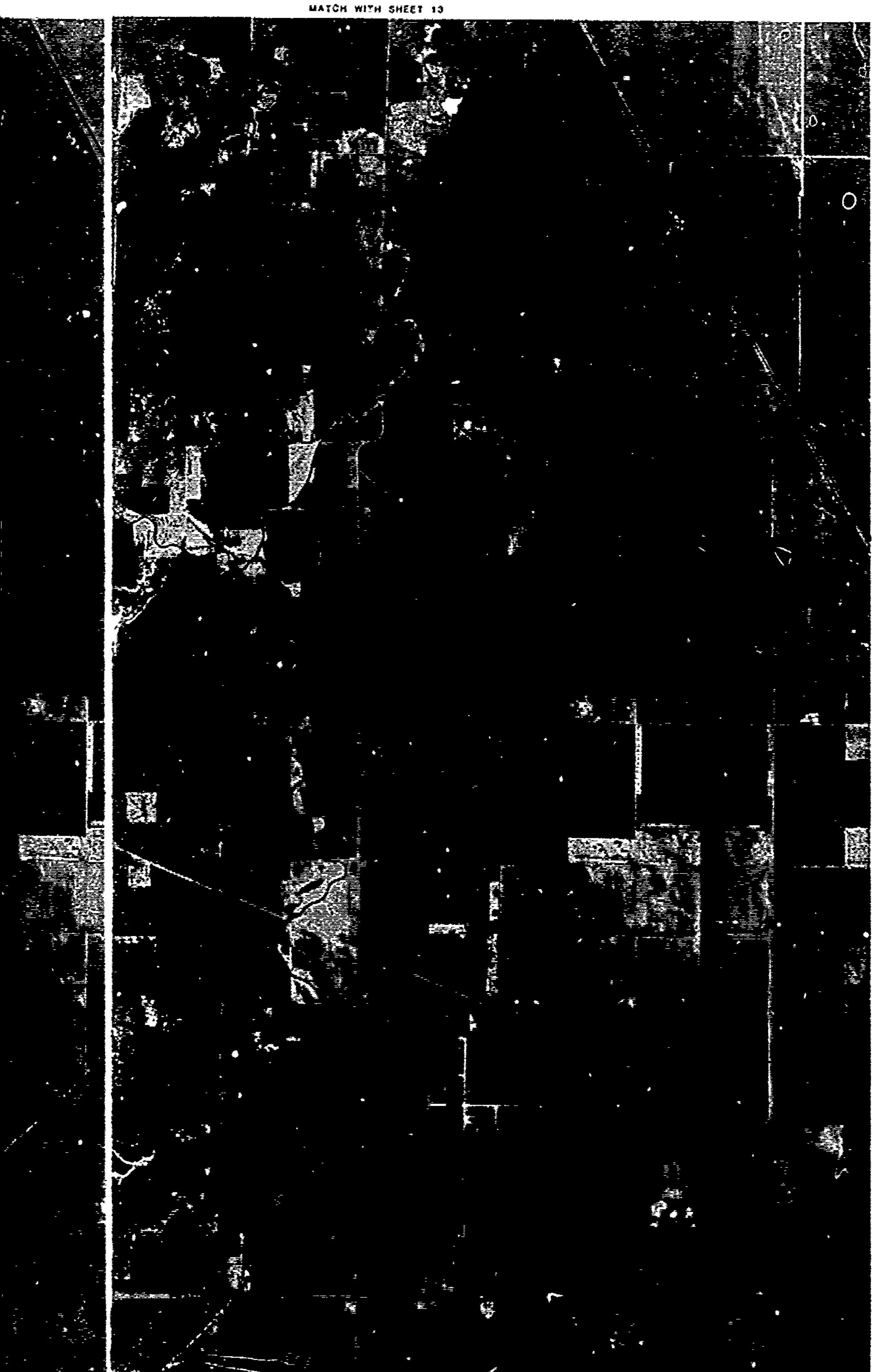

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SCALE IN MILES

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1 : 24,000

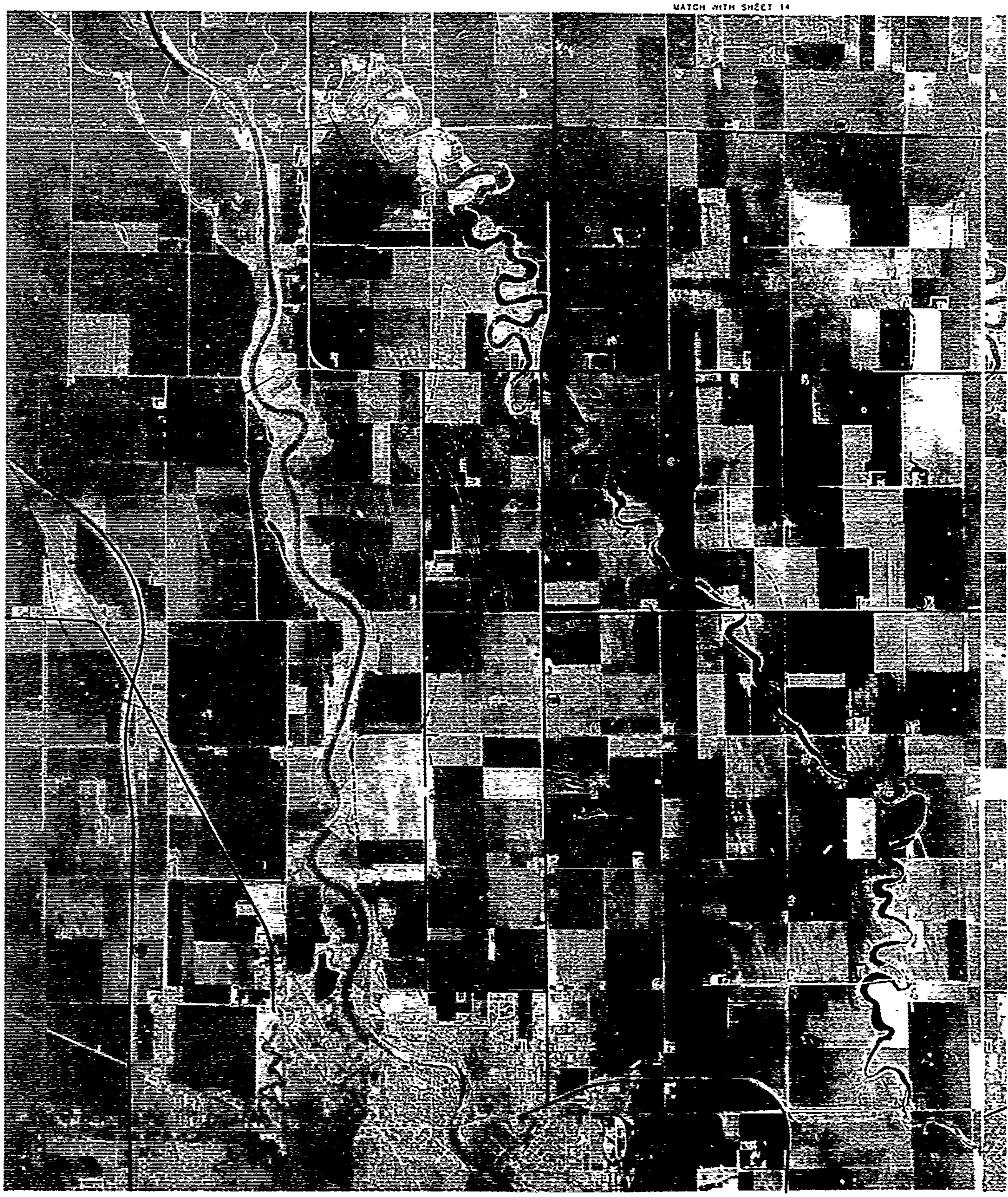
CORPS OF ENGINEERS, U.S. ARMY

ST. PAUL DISTRICT · ST. PAUL, MINNESOTA

RED RIVER VALLEY

SHT. 15 OF 16

MATCH WITH SHEET 14



MATCH WITH SHEET 15

WESTON

PHOTOGRAPHY COMPLETED : JULY 16, 1979

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SCALE IN MILES

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MATCH WITH SHEET 14

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SCALE IN MILES

N

1 : 24,000

CORPS OF ENGINEERS, U.S. ARMY
ST. PAUL DISTRICT - ST. PAUL, MINNESOTA
RED RIVER VALLEY
SHT. 16 OF 16

APPENDIX F

CORRESPONDENCE

TABLE OF CONTENTS

STATE OF
MINNESOTA
DEPARTMENT OF NATURAL RESOURCES

BOX , CENTENNIAL OFFICE BUILDING • ST. PAUL, MINNESOTA • 55155

DNR INFORMATION
(612) 296-6157

FILE NO.____________

August 7, 1981

Mr. Vernon Fahy, State Engineer
North Dakota State Water Commission
State Office Building
900 East Boulevard
Bismarck, North Dakota 58505

Dear Mr. Fahy:

RED RIVER AGRICULTURAL DIKE CORRECTIVE PLAN DEVELOPMENT

I'm sure you have been kept apprised of the progress of the above effort and that the local water management entities have not been able to agree on a corrective plan. I do believe, however, that the local board negotiators have been conscientious and diligent in their efforts to reach an agreement and that the meetings have been successful in resolving numerous areas of concern between the local boards.

The primary issue which has not been resolved is the degree of protection that would be afforded by the corrective plan. At the present time, the local boards of North Dakota advocate 35,000 cfs protection with an apparent willingness to compromise on 39,000 cfs. The Middle River-Snake River Watershed District in Minnesota advocates a minimum 43,000 cfs level of protection, assuming equal protection on the North Dakota side. The key point is that both sides appear to have relaxed their hard-line positions of in the past: one side insisting that the Minnesota dikes be completely removed, and the other opposing any lowering of the existing dikes whatsoever. In simple terms, local interests in North Dakota are now requesting that the Minnesota dikes be lowered an average of 4 feet with some possibility of compromising on a 3.5-foot reduction. The Middle River-Snake River Watershed District is at this point willing to accept a 1.5-foot average lowering. (Note: The term "average lowering" refers to an approximate arithmetic mean for the entire diked reach and implies neither that lowering of the amount will occur at each cross section, nor that some limited raising of certain diked areas will not occur).

Because local agreement on these issues is not yet complete, I believe our respective agencies have an obligation to attempt to arrive at a solution with which the local boards can agree. Accordingly, the following proposal is submitted for your consideration:

1. That consistent with the experienced 1975 rain-caused flood, the degree of protection be based upon a discharge of 43,000 cfs, which closely approximates a 10-year frequency flood. We find little basis

for reducing the hydrologic design below the experienced summer flood discharge from which farmers on both sides of the river set out to protect themselves when dike construction was first initiated.

2. That the corrective plan provide for the removal of "points" or other bottlenecks which will improve the hydraulic efficiency of the levee system and provide for better flow distribution. This action alone can lower flood stages up to one foot with levees on both sides or up to 0.5-foot with levees on one side only.

3. That in recognition of the tributary-caused difficulty, if not impossibility, of providing a reasonable, practical, and economical dike system for this reach of the Red River on the North Dakota side, and consistent with the position most recently taken by the affected boards that diking in North Dakota will and is diminishing rather than increasing, appropriate consideration be given to the Section J Exception to the criteria of the Joint and Cooperative Agreement between our respective states which provides for reasonable accomodations to the hard and fast application of the criteria. Such an approach is all the more warranted when one considers that the technical evaluation assumes noneffective flow area landward of and below the Minnesota dikes, while giving full credit for the undiked overbank areas in North Dakota. In reality, roadways, driveways, and spoil banks detract from the carrying capacity of these overbank areas, which is not considered the model. This would, with 43,000 cfs, provide for an average 2.5-foot reduction in levee height.

4. That in order to simplify contracting procedures for the disbursement of Minnesota's legislative appropriation for dike modification and to provide for effective day-to-day administration of the dike system, efforts be made to establish the corrective plan as a watershed district project rather than an amalgamation of separate property owners.

I'm certain you will agree that the aforementioned $750,000 appropriation for state cost sharing to implement the corrective plan through this Division and the Middle River-Snake River Watershed District is a very positive step. Hopefully, through our efforts at the state level, ultimate concurrence of the local boards, which is so necessary, will be achieved.

My staff suggests that if you concur with the suggested 43,000-cfs level of protection, a technical representative from each state and the Corps of Engineers prepare a technical report on the hydraulic analyses, including all assumptions, prior to our discussion of points 2 through 4 above.

Please advise me of your thoughts in the matter.

Sincerely,

DIVISION OF WATERS

Larry Seymour
Director

LS/jl

NORTH DAKOTA
STATE WATER COMMISSION
900 east boulevard
701-224-2750
bismarck 58505
north dakota

September 18, 1981

Larry Seymour, Director
Division of Waters
Department of Natural Resources
Centennial Office Building
Box 32
St. Paul, Minnesota 55155

RE: SWC Project File #1638

Dear Mr. Seymour:

This is in response to your letter dated August 7, 1981, concerning the efforts to develop an acceptable corrective plan for the Red River agricultural dikes, and thus implement the February, 1980 agreement between North Dakota and Minnesota. I have also been kept apprised of this effort, and while I am hopeful that we can resolve this matter in the very near future, I am disappointed that the local water management entities have not been able to agree on a corrective plan.

You indicate in your letter that the degree of protection that would be afforded by the corrective plan is the primary unresolved issue. You also indicate that the local boards of North Dakota advocate 35,000 cfs protection, with a willingness to compromise on 39,000 cfs protection, and that the Minnesota local boards advocate a minimum of 43,000 cfs protection, assuming equal protection on the North Dakota side. You state that since the local water management entities have not been able to resolve this issue, our respective state agencies have an obligation to arrive at a mutually acceptable solution. You then submit a proposal for our consideration.

First of all, I strongly support all efforts by our respective states agencies to resolve this matter as soon as possible, in a manner which is acceptable to the local interests on both sides of the river. In that regard, I stand ready to give this matter vigorous and foremost attention, to ensure settlement as soon as possible. I will address each component of your proposal separately. The first paragraph of your proposal provides:

Larry Seymour
September 18, 1981
Page 2

"1. That consistent with the experienced 1975 rain-caused flood, the degree of protection be based upon a discharge of 43,000 cfs, which closely approximates a 10-year frequency flood. We find little basis for reducing the hydrologic design below the experienced summer flood discharge from which farmers on both sides of the river set out to protect themselves when dike construction was first initiated."

The 43,000 cfs discharge is approximately a 10-year frequency flood, however, the 1975 rain-caused summer flood which was recorded at approximately 43,000 cfs in the Oslo area, was the largest summer flood of record, far in excess of a 100-year summer flood.

A review of the Corps hydrologic analysis indicates that 43,000 cfs protection for the Minnesota side only would result in a top of levee elevation of approximately one (1) foot above the observed 1975 flood level, and equal protection for both sides would require a top of levee elevation of two (2) to three (3) feet above the 1975 observed flood level. 35,000 cfs protection for the Minnesota side only would require a top of levee elevation at the approximate 1975 observed flood level.

Since you agree that it would be impossible for the North Dakota farmers to provide the same degree of protection as the Minnesota farmers, I find little basis for any plan that would allow a top of levee elevation above the observed flood level of the 1975 summer flood, this being the level farmers on both sides of the river initially attempted to provide protection for. Agreement on a plan which would allow the levees to be higher than the 1975 level would result in widespread da . es on the North Dakota side. The original intent of the farmers w constructed the levees was to protect themselves against an extremely rare summer flood. This being the case, it is not equitable to allow construction of levees intended to protect against such a rare summer occurrence, which also results in severe damages on an almost annual basis upon the occurrence of spring floods.

Your second paragraph proposes that bottlenecks be removed. I agree with the concept that the corrective plan provide for the removal of "points" or other bottlenecks to improve the hydraulic efficiency of the levee system and provide for better flow distribution. The extent to which this action will lower flood stages will have to be determined as the specific bottlenecks are identified. It is my understanding that the local interests also support this concept, and if so, the corrective plan can specifically delineate those points or bottlenecks to be removed.

I also agree that appropriate consideration should be given to the Section J Exception to the criteria of the Joint and Cooperative Agreement between our respective states. The proposal I have presetned takes this into consideration since the resulting impact on the 100-year flood is much greater than the allowable agreed upon one-half foot.

Finally, to simplify contracting procedures and for effective day-to-day administration of the levee system, you suggest that efforts be made to establish the corrective plan as a watershed district project rather than an amalgamation of separate property owners. It has always been my intention that the North Dakota portion of the corrective plan would be a Water Resource District project. This approach clearly provides the most efficient and practical method of implementing the corrective plan.

I am willing to allow the level of protection to be increased from 35,000 cfs to 39,000 cfs, as have the local water management entities. I also agree that if you concur with the suggested 39,000 cfs level of protection, a technical representative from each state and the Corps of Engineers prepare a technical report on the hydraulic analyses, including all assumptions.

In conclusion, I restate that I am anxious to pursue this matter to appropriate resolution. Since we are not able to fully accept your proposal, it is suggested that we meet to discuss this matter on October 20 or October 27. A mutually agreed to meeting location can be selected at a later time. Hopefully, one of these dates will be convenient for you and your staff.

Sincerely,

Vern Fahy

Vern Fahy
State Engineer

VF:MD:DAS:ps

North Dakota State Water Commission

GOVERNOR ALLEN I. OLSON
CHAIRMAN

VERNON FAHY
SECRETARY & STATE ENGINEER

February 26, 1982

William W. Badger, Colonel
St. Paul District Corps of Engineers
1135 U.S. Post Office & Custom House
St. Paul, MN 55101

RE: SWC Project #1638

Dear Colonel Badger:

Thank you for the opportunity to review the draft Technical Information Report on the Red River of the North Mainstem. The St. Paul District is to be commended for the time and energy put into the development of this document. We believe the final report will be quite functional and valuable for our needs. Furthermore, the way in which the report was put together makes it very easy to use.

Based on our review, we have the following comments to offer. In the introduction to the report, it is indicated that in early 1980 the Governors of Minnesota and North Dakota agreed on levee criteria and that the primary requirement is that the levees may not increase the stage of the 100 year flood on the Red River by more than 1/2 foot. The emphasis that this is the primary requirement is quite important, but it should also be pointed out that Section J of the Agreement does allow exceptions to the 1/2 foot criteria. It was under the authority of Section J that the local Watershed District in Minnesota and the Water Resource Districts in North Dakota attempted to develop a compromise solution for the existing agricultural levees. Mention is also made in the introduction of the cooperation with the Premiere of Manitoba. It should be stressed that involvement of the Manitoba government was very limited, and that the agreement has not been approved by Manitoba.

In the section entitled "Analysis of Existing Agricultural Levees and Proposed Modifications", there is discussion on increased flow velocities caused by the levees, resulting in the potential for increased erosion. It should definitely be pointed out that a considerable amount of erosion on the North Dakota floodplain has taken place downstream from Oslo since the construction of the levees. The increased flow velocities caused by the levees as well as the additional water diverted onto the North Dakota side have been the cause of this increased erosion.

In this section it is also pointed out that in reaches 3 and 4, a much greater number of farmsteads in North Dakota compared to the number of farmsteads in Minnesota have been protected by ring levees. This clearly indicates the awareness of the increased flooding due to the agricultural levees as well as the concern of the local landowners relative to the increased flooding on the North Dakota side.

There is also a discussion on the current status of modification plans within this section. The report indicates that Grand Forks and Walsh County Water Management Boards propose a level of protection not to exceed 39,000 cfs. This is not correct. The proposal put forth by the Water Resource Districts in North Dakota was that the dikes on the Minnesota side would be modified to provide 35,000 cfs protection for Minnesota; and that the existing dikes on the North Dakota side would not be raised or extended. The 39,000 cfs protection for the Minnesota side was discussed as a possible compromise plan between the two states, however, this compromise plan has not been accepted by either side as of this date. The proposal put forth by the North Dakota Water Resource Districts, 35,000 cfs, would allow the top of levee elevations on the Minnesota side to be at or near the observed 1975 flood profile. This was represented in your analysis known as Case 36. The report also discusses the hydraulic effects of bridges and approach roads and the spoil banks along Minnesota Judicial Ditches #1 and #75. Although the computer analysis indicates increased backwater due to these structures, the effect does not appear to be as significant as local landowners believe it to be. One of the reasons for this may be that the computer analysis was made for the 1% chance flood, whereas the people in the local areas are more familiar with the effects of the more frequent floods that have occurred in recent years. In order to have a better comprehension of the hydraulic effects of these structures, additional computer analysis should be made on more frequent events, to include the 5, 10, 25, and 50 year flood events. It should also be noted that aerial photographs taken during recent floods show very clearly the substantial flooding that results upstream of the spoil banks located adjacent to Judicial Ditch #75. This additional flooding results on the North Dakota side as well as the Minnesota side of the river.

In the section "Guidelines for Agricultural Levee Construction", there is a discussion on soil foundation guidelines. This states that to build a levee properly requires a greater initial investment than the levees that have already been built, and also points out that the existing levees have, in some areas, performed their function. However, it must be noted that in many areas, the levees have failed. Furthermore, it should be noted that if the dikes are raised and constructed on both sides as has been proposed by the Middle River-Snake River Watershed District, the potential for foundation failure will be greatly increased. This also will have an effect on the navigability of the river.

In closing, I want to thank the St. Paul District for a very well-prepared and well-written report. I hope that the final published document can be available very soon.

Sincerely yours,

David A. Sprynczynatyk

David A. Sprynczynatyk, P.E.
Director of Engineering

DAS:sh

STATE OF
MINNESOTA
DEPARTMENT OF NATURAL RESOURCES

BOX , CENTENNIAL OFFICE BUILDING • ST. PAUL, MINNESOTA • 55155

DNR INFORMATION
(612) 296-6157

FILE NO.

April 27, 1982

Colonel William Badger
U.S. Corps of Engineers
1135 U.S. Post Office & Customs House
St. Paul, MN 55101

Dear Colonel Badger:

The review of the Technical Information Report has been completed and several of our comments have been discussed with your staff. I'll briefly discuss the comments as follows:

1. Page 3: The 100-year flood discharge at Grand Forks was determined by the interagency committee to be 89,000 cfs., yet the document states that the Corps uses $106,000 cfs for its planning and design. It is not clear that the Corps considers 106,000 cfs to be the 100-year or a less frequent discharge. The USGS was asked by the USCE to review the current information with the intent to change the 100-year discharge. I understand that the U.S.G.S. did not consider the data to be sufficient to warrant the change advocated by the Corps. Therefore it may be appropriate to omit this from the document. In any case, it would be beneficial to identify those agencies involved in the interagency hydrology review committee.

2. Page 30: Footnote 3 should read "would" instead of "would not". Damages are not listed and in fact the levees would be effective for the 1978 event.

3. Page 31: Footnote 1 does not explain anything about why no benefits are received in North Dakota reaches 2 and 3. It appears that a footnote is missing somewhere. Figure 11 actually shows benefits achieved from the levees.

4. Page 32: The per acre damages listed in Table 6 (page 24) are assumed to be used in the development of Table II, however the numbers are substantially different. The variation should be explained.

5. Page 38: Figure 15, Figure 5 and Figure 4 give inconsistent values for the beginning and ending mileage points for the Minnesota and North Dakota levees. If the differences represent different time periods then this should be stated or otherwise clarified.

6. Page 33: The last sentence of the first paragraph should read stages rather than storages.

7. Page 108: This section discusses the impacts of bridges and bridge approaches. The evaluation should recognize that the crossings may have greater impact if over the road flow which presently exists was eliminated by future roadway improvements.

8. Page 114: Table 20 has a footnote (1) indicator but no footnote exists.

9. Page 99: The summary of the Middle River-Snake River Watershed District is somewhat misleading. The fourth component refers to Case 41 which was not part of the District proposal. This sentence should be eliminated and if some comparison is desired, a footnote may be more appropriate.

   The summary of the Grand Forks and Walsh County proposal needs clarification. In component one 35,000 cfs may be more appropriate while recognizing that the two counties were willing to and did, in writing compromise to 39,000 cfs.

   The second component is incorrect in that North Dakota would raise existing levees to the Minnesota levee elevation but would not extend existing levees. The proper statement could be taken directly from the county proposal.

   The last sententce of the page should be followed by a brief summary of Minnesota and North Dakota proposals for resolution. Otherwise the implication is that the matter was resolved. I am attaching correspondence which sets forth the states' proposals and a letter summarizing the discussion from the October 27, 1981 meeting between the Minnesota Department of Natural Resources and the North Dakota State Water Commission.

In summary, the document is very well done particularly in light of the technical content. The document constitutes a substantial effort on the part of your agency to assist state and local government in attempting to resolve a very sensitive issue. Although a resolution was not formalized to date, the document will provide the basis for future discussion on levees and provide a

wealth of information for other flood plain activities and discussion. Your agency's assistance in these activities is greatly appreciated and definitely needed now and in the future to address the problems of the Red River Valley.

Yours truly,

DIVISION OF WATERS

Ronald D. Harnack

Ronald D. Harnack, Administrator
Land Use Management Section

RDH/jl

cc: Jerry Paul
Kevin Cook